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COMPUTER PROGRAMS FOR ESTIMATING THE COST OF PARTICULATE CONTROL EQUIPMENT

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COMPUTER PROGRAMS FOR ESTIMATING THE COST OF PARTICULATE CONTROL EQUIPMENT

by

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ABSTRACT

An interactive computer program has been written to estimate the capital and operating expenses of electrostatic precipitators, fabric filters, and venturi scrubbers used on coal-fired boilers. The program accepts as input the current interest rate, coal analysis, the emission limit, and the design and operating parameters of the control device. The installed cost of the collector and the annual fixed and variable operating and maintenance costs are estimated. Based on the interest rate specified, an annual payment of interest and principal is calculated for the amount of capital required. This annual capital cost is added to the annual operating and maintenance costs to yield a total annual cost of the collector. A comparison between reported and predicted costs indicates that the model is capable of ±25 percent accuracy.

CONTENTS

Section Page

Abstract . . . iii
Figures. . . . vii
Tables ix

1 Introduction 1
1.1 Purpose 1
1.2 Overview. . . . 2

2 Conclusions and Recommendations. . . . 3
2.1 Conclusions 3
2.2 Recommendations 3

3 Comparison of Program Results with Published Data. . . . 5
3.1 Discussion of Comparisons 12

4 Description of Cost Models 17
4.1 Overview. . . . 17
4.2 Capital Cost Estimation 17
  4.2.1 ESP/Baghouse Capital Cost Models 19
  4.2.2 ESP Cost Model 19
  4.2.3 Fabric Filter Cost Model 20
  4.2.4 ID Fan Cost. . . . 22
  4.2.5 Ash Pond Cost. . . . 23
  4.2.6 Turnkey Cost 25
4.3 Scrubber Capital Cost Model 25
  4.3.1 Turnkey Cost 29
4.4 Annual Capital Cost 29
4.5 Operating and Maintenance Costs 29
  4.5.1 ESP Operation and Maintenance. . . . 30
  4.5.2 Fabric Filter Operation and Maintenance. . . . 31
  4.5.3 Scrubber Operation and Maintenance 33
4.6 Total Annual Cost 34

5 User Instructions. . . . 35
5.1 System Requirements 35
5.2 A Word About Floppy Diskettes 35
5.3 First-Time User 36
5.4 Sample Session of Cost Program Execution. . . . 37
5.5 Description of Program Output 58

6 Other Programming Considerations 61
6.1 Discussion of Flow Rate and Emissions Calculations. . . 61
6.2 COST Program Data Files 64

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CONTENTS (continued)

Section Page

6.3 Extension of the Program to Novel Devices 64
6.4 Miscellaneous Speculation 64

7 References 67

APPENDIXES

A Glossary A-1
B Cost Comparison Details. B-1
C Program Listings C-1
D Program Cross-Reference. D-1
E Data Input Worksheets. E-1

FIGURES

Number		Page
1	Comparison between actual and predicted costs in 1978 dollars	7
2	Economy of scale for fabric filters, predicted and actual costs in 1978 dollars	11
3	Economy of scale for predicted and actual turnkey costs (1978 dollars) of fabric filters	13
4	Plant input worksheet	38
5	COST program flow sheet	39
6	The beginning of the COST program	41
7	Identifying a plant and selecting units	41
8	Page 1 of plant data	43
9	Changing a plant parameter	43
10	Page 2 of plant data	45
11	Entering a large number	45
12	The program will create a plant file	47
13	Selection of a control device	47
14	Preliminary ESP information	48
15	Page 1 of ESP data showing default values	48
16	Page 2 of ESP data showing default values	49
17	Video display of program results	49
18	Page 1 of the hard-copy listing showing the plant data	51
19	Page 2 of the hard-copy listing showing ESP input data and the cost results	51
20	Restarting the program	52
21	Hotside ESP costs	52
22	Pages 1 and 2 of fabric filter data showing default values	53
23	Video display of the default case fabric filter costs	54
24	Pages 1 and 2 of venturi scrubber data showing default values	54
25	Costs for the default case venturi scrubber	55
26	Retrieving plant data from a file	55
27	Displaying record information	57
28	Obtaining a hard-copy listing of a file's contents	57
29	Hard-copy of file directory	59
30	Retrieving device data	59
31	ESP data file structure	65

TABLES

Number		Page
1	Sources of Cost Data on Actual Installations	6
2	Nucla Costs Summary.	8
3	Kramer Costs Summary	9
4	Sunbury Costs Summary.	9
5	George Neal Costs Summary.	10
6	Navajo Costs Summary	10
7	Model Parameters for a Coldside ESP.	21
8	Model Parameters for a Hotside ESP	21
9	Model Parameters for Small ESPs.	21
10	Model Parameters for Fabric Filters.	23
11	Model Parameters for Duct Cost Per Module.	26
12	Cost of a Clarifier as an Integral Part of an FGD System . .	27
13	Cost of a Clarifier Independent of an FGD System	28
14	Electrical Requirements Per Unit Area for Accessories and Ash Handling System.	31
15	Unit Maintenance Costs for Precipitators	31

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SECTION 1

INTRODUCTION

1.1 PURPOSE

The economic feasibility of a pollution control operation is determined by a cost (or investment) analysis. A complete cost analysis includes, but is not limited to, capital investment estimation, annual expense estimation, interest and depreciation factors, taxes, and various measures of merit. This analysis cannot be performed until the process design has been developed. Once the process design is established, the first step in a cost analysis is the determination of capital and operating costs for the project. If several pollution control options are to be evaluated, the work involved in cost estimation can be very time-consuming.

The purpose of this report is twofold: (1) to present and discuss a model for capital and operating cost estimation for fabric filters, electrostatic precipitators, and venturi scrubbers; and (2) to present a computer program that was developed to facilitate use of the model. The model requires the design data for the plant and the control device and predicts the installed cost of the collector, the annual fixed and variable operating and maintenance costs, and an annual payment of principle and interest based on the capital cost and interest rate. The model does not make design calculations nor does it perform a complete cost analysis. Models for design of fabric filters, electrostatic precipitators, and venturi scrubbers are available in the literature. Methods of cost analysis are well described in the report by Uhl.[1]

The model is capable of predicting costs to within ±25 percent of the correct value; however, these results are not guaranteed. The accuracy of any prediction is highly dependent on the accuracy of the design data. Any errors in design data will be reflected in the cost estimates. There is no provision in the model for estimating retrofit costs so the user must make this correction if necessary.

1.2 OVERVIEW

This report consists of several independent sections for quick reference. Section 2 lists the conclusions and recommendations resulting from this study. The details of the model validation are described in Section 3 along with a discussion of the results. The models used to predict the capital and operating costs are presented in Section 4. A "typical" system for each case (ESP, baghouse, and scrubber) is specified and the data used to develop the equations are described. A complete set of instructions on the use of the cost computer program that was developed from these models is included in Section 5. This section should be especially useful for the "first time user" who needs basic information about the computer as well as instructions on how to run the program. Section 6 describes implementation of this program on a computer other than the TRS-80® and gives some helpful hints on altering the program, should the need arise.

A glossary is included as Appendix A, Appendix B compares cost details, Appendixes C and D present an annotated listing of the program and a cross-reference of program variables and line numbers, and Appendix E offers examples of data input worksheets.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

2.1 CONCLUSIONS

1. An empirical model has been developed to predict the cost of air pollution control devices. If accurate design data are available and there are no unusual design requirements, the model is capable of ±25 percent accuracy.

2. A computer program has been written to facilitate use of the model. The program is fast and easy to use.

3. The model is not capable of predicting costs for control devices of novel design because it estimates cost based on the cost of an existing unit of similar design.

2.2 RECOMMENDATIONS

1. The ID fan, ash pond, and scrubber train equipment models discussed in this report are based on 1973 data. Some of these data may be obsolete because of changes in process design. New correlations should be developed for these items.

2. The base case ESP and fabric filter designs include positive pressure ash disposal systems, which are not as common as the hydro-vac type. The cost models should be developed for the hydro-vac ash system and incorporated into the computer program.

3. Published values of operating and maintenance costs should be surveyed to obtain data for verification of model predictions. Changes should be made where necessary.

4. Performance models for electrostatic precipitators, baghouses, and scrubbers should be implemented on the TRS-80® microcomputer and coupled to the COST program. This would further reduce the time required to obtain data for an investment analysis.

5. The usefulness of the program with respect to industrial boilers can be enhanced by developing a cost model for pulse jet baghouses.

6. A more detailed model that does not rely on costs of existing units should be developed. Increased detail would increase the complexity of the model; however, it would also result in better accuracy. If

such a model were based on simple components (e.g., amount of ductwork, amount of structural steel, number of pumps, fans, etc.) then the model could be used to estimate the cost of a control device based on a novel design.

SECTION 3

COMPARISON OF PROGRAM RESULTS WITH PUBLISHED DATA

The data from which the cost models were developed are actually estimates of equipment costs published by Campbell et al.,[2] Ponder et al.,[3] and Kinkley and Neveril.[4] Thus it is prudent to compare the results of the program with published values of pollution equipment costs to verify the accuracy of the cost models. This test is an objective comparison of the model's ability to predict costs. In making such a comparison, we wanted to obtain the most reliable data available, avoiding "off the cuff" guesses, poorly documented cost data, and estimates from models similar to our own. These considerations required that the data be very detailed and, preferably, that they be obtained from the accounting records of the project by an independent third party (i.e., other than the vendor or owner) to ensure objectivity.

A search of the literature revealed a small number of reports that include capital cost data for particulate control devices. These references are listed in Table 1. The TCA scrubber cited in Table 1 is used solely for particulate scrubbing. While the model is designed to estimate the cost of a venturi scrubber, no cost data were available for venturi scrubbers. Therefore, assuming that most components of a scrubber train are the same regardless of the particulate scrubbing mechanism, the TCA data are used here to validate the model. The following procedure was used to predict the cost of those units: First, the design and operating information was obtained from the appropriate report. Next, assumptions were made to fill in gaps in the data. For instance, values for load factors and duty factors (see Glossary for definitions) were chosen and it was then assumed that these values were the same for all control devices. After all of this information was gathered it was necessary to choose reasonable values for engineering and contingency costs. In all cases a value equal to 20 percent of the total field cost was assumed for both engineering and contingency. This information was then used as input to the COST computer program (see Section 5) to estimate costs in the year of construction.

For comparisons to be made on an equal basis, it was necessary to account for the retrofit costs associated with some of the control devices. Where the information on retrofit costs was available, these costs were subtracted from the reported total field cost. For those cases where this information was not available, it was assumed that the retrofit costs were equal to 10 percent of the total field cost based on recommendations by Ensor et al.[5]

The cost information in the reports cited in Table 1 varies considerably in the level of detail. Some reports list a complete breakdown of the cost of the collector, the cost of the ductwork, insulation costs, ash system costs, etc., while others report only the total field cost of the unit. For those cases where detailed information is available, a rigorous comparison of predicted versus actual costs has been made. The results of these comparisons are listed in Tables 2 through 6. The procedures used in developing these comparisons are given in the Appendix B. An overall comparison of costs on a turnkey basis including all of the control devices cited in Table 1 is presented in Figure 1.

TABLE 1. SOURCES OF COST DATA ON ACTUAL INSTALLATIONS

Plant	Type of collector	Size (MW)	Year of installation	Citation
Cherokee #3 (r)	TCA wet scrubber	160	1971	Ensor et al.[6]
Nucla (r)	Baghouse	38	1974	Ensor et al.[7]
Kramer (r)	Baghouse	115	1977	Ensor et al.[5]
Sunbury (r)	Baghouse	175	1973	Cass and Bradway[8]
Shawnee (r)	Baghouse	1,750	1978	Hudson et al.[9]
Harrington #2	Baghouse	350	1977	Turner[10]
George Neal #3	ESP coldside	500	1975	Ensor et al.[11]
Plant A	ESP hotside	576	1975	Sparks[12]
Navajo	ESP hotside	750	1977	Gooch and Marchant[13]

(r) = retrofit.

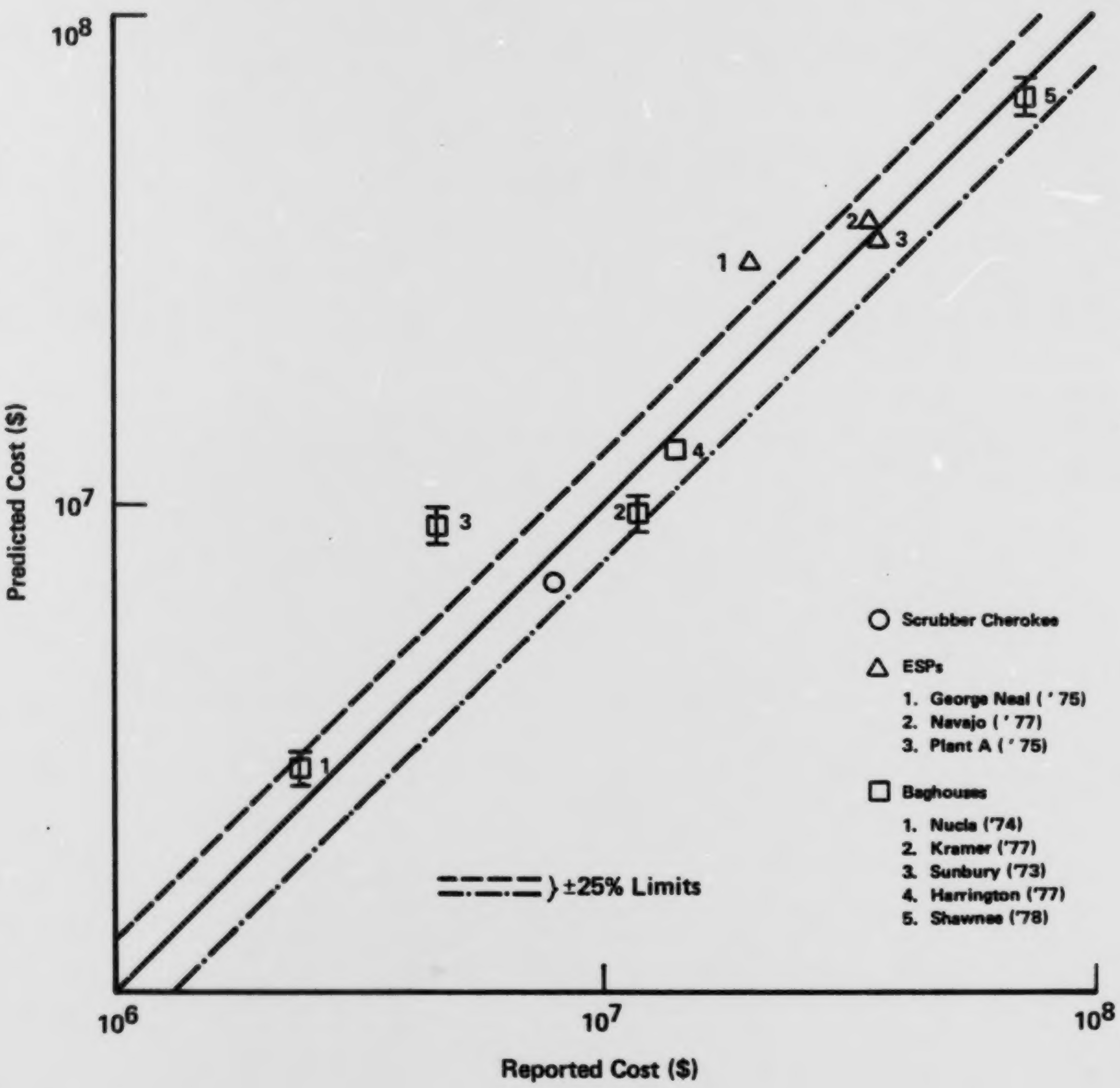


Figure 1. Comparison between actual and predicted costs.

TABLE 2. NUCLA COSTS SUMMARY
(1974 Dollars × 10^3)

	Reported	Predicted[a]	Predicted[b]
Collector & supports[c]	957	800	864
Ducting & supports	182	147	200
Ash removal system	199	169	150
Insulation	130	280	309
Miscellaneous	592	506	522
Total field cost	2,060	1,900	2,040
Engineering	300	430	480
Contingency	44	430	480
Turnkey cost	2,400	2,760	3,000

[a] One 36-MW baghouse.

[b] Three 12-MW baghouses.

[c] Refer to glossary for definitions.

Another comparison was warranted by the availability of five fabric filter cost cases. With the information on several units of different sizes, it is possible to compare the model's ability to predict the economy of scale (i.e., cost per unit size). This is of particular interest because Campbell et al.[2] reported a relatively large economy of scale for baghouses and almost no economy of scale for ESPs. There are a number of ways to present scaleup costs and each has its limitations. In the utility industry, where the cost per unit of the product (power) is the major interest, it is common practice to report costs in terms of dollars per kilowatt. However, this practice might conceal differences in collector design such as collector area. An undersized collector could have a very low dollar-per-kilowatt cost but may not work as anticipated. The dollars per kilowatt for the various cases are summarized in Figure 2.

A second approach is to consider dollars per collector area as a function of collector area. This approach is useful to determine if there truly is an economy of size. This analysis is probably most suitable for industrial

TABLE 3. KRAMER COSTS SUMMARY
(1977 Dollars × 10^3)

	Reported	Predicted[a]	Predicted[b]
Collector & supports	6,140	2,920	3,220
Ducting & supports	720	310	460
Ash removal system	330	540	460
Insulation	870	970	1,080
Miscellaneous	2,180	1,770	1,840
Total field cost	10,240	6,510	7,060
Less 10% for retrofit	-1,020	-	-
	9,220	6,510	7,060
Engineering	1,560	1,360	1,510
Contingency	950	1,360	1,510
Turnkey cost	11,730	9,230	10,080

[a] One 115-MW baghouse.

[b] Three 25-MW baghouses plus one 40-MW baghouse.

TABLE 4. SUNBURY COSTS SUMMARY
(1973 Dollars × 10^3)

	Reported	Predicted[a]	Predicted[b]
Collector & supports Ducting & supports Insulation	2,450	3,910	4,350
Ash removal system	1,060	540	470
Miscellaneous	520	1,720	1,760
Total field cost	4,030	6,170	6,580
Less 10% for retrofit	-400	-	-
	3,630	6,170	6,580
Engineering	880	1,310	1,440
Contingency	240	1,310	1,440
Turnkey cost	4,750	8,790	9,460

[a] One 175-MW baghouse.

[b] Four 44-MW baghouses.

TABLE 5. GEORGE NEAL COSTS SUMMARY
(1975 Dollars × 10^3)

	Reported	Predicted[a]	Predicted[b]
Collector & supports	11,200	12,100	12,300
Ducting & supports	2,100	3,360	3,760
Ash removal system	1,700	1,450	1,700
Insulation	1,200	1,390	1,420
Miscellaneous	3,200	7,580	7,490
Total field cost	19,400	25,900	26,700
Engineering	600	4,520	4,720
Contingency	c	c	c
Turnkey cost	20,000	30,400	31,400

[a] Cost computed for one large 530-MW ESP.

[b] Cost computed as twice the cost of one small 265-MW ESP.

[c] Contingency has been factored into equipment costs.

TABLE 6. NAVAJO COSTS SUMMARY
(1977 Dollars × 10^3)

	Reported	Predicted[a]
Collector & supports	16,350	9,380
Ducting & supports	4,070	6,080
Ash removal system	8,920	720
Insulation	2,160	2,150
ID fan	450	1,630
Miscellaneous	1,850	12,100
Total field cost	33,860	32,030
Engineering	a	a
Contingency	1,130	5,300
Turnkey cost	35,000	37,300

[a] Engineering has been factored into equipment costs.

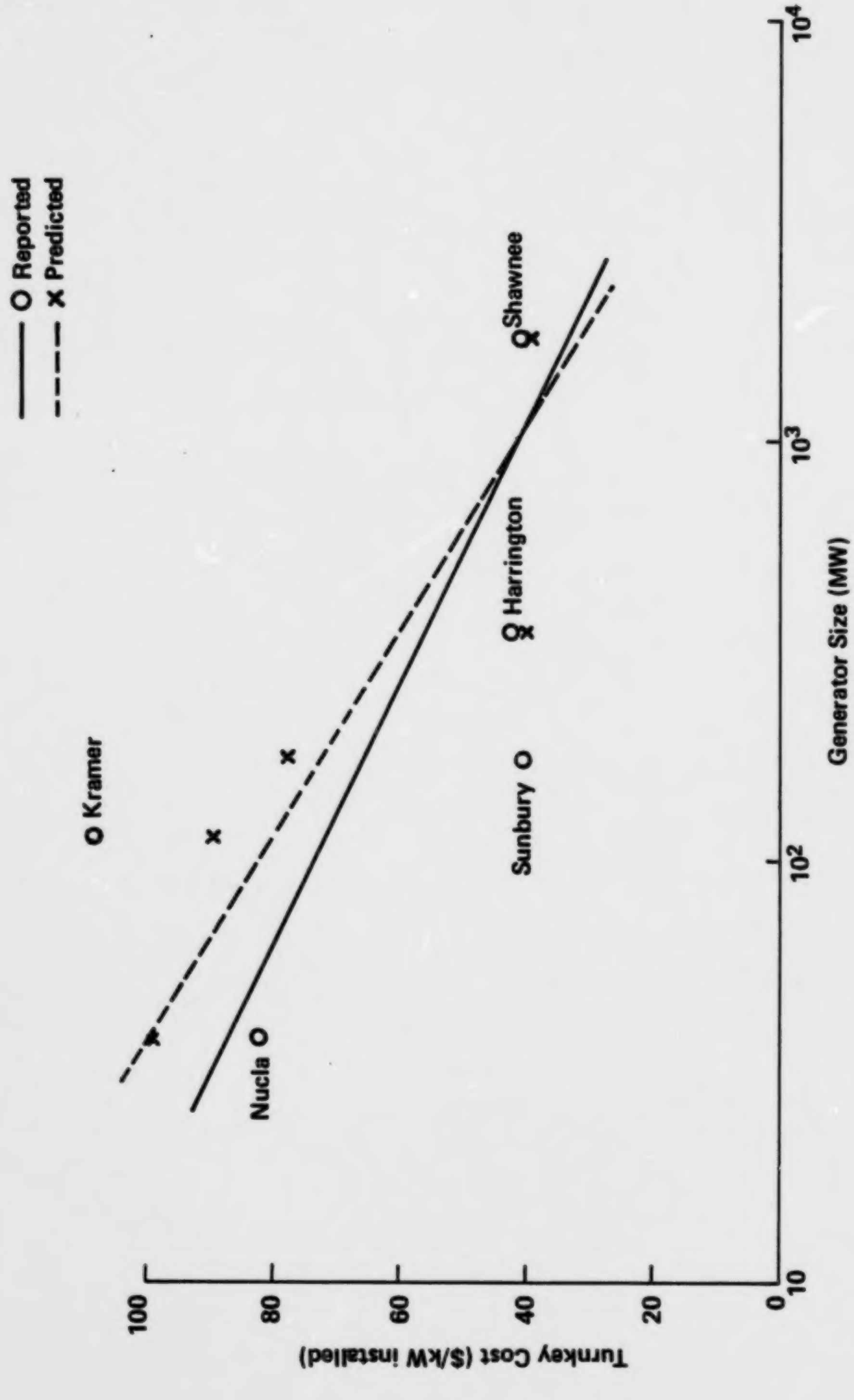


Figure 2. Economy of scale for fabric filters, predicted and actual costs in 1978 dollars.

sources; however, it can provide important information to the utility sector as well. One advantage of the collector area unit cost is that diverse designs can be directly compared. The major disadvantage is that the specific collection areas are not directly taken into account. The unit costs based on collection area are presented in Figure 3.

3.1 DISCUSSION OF COMPARISONS

Tables 2 through 5 contain two columns of numbers labeled "Predicted." The first of these columns presents costs based on a single, large control device, and the second column presents costs based on two or more smaller control devices. The reason for these two predictions can be illustrated with the Nucla baghouse in Table 2. The Nucla plant actually uses a separate baghouse on each of its three 12-MW boilers. Predicting the cost of three control devices as though they were separate projects tends to neglect the fact that some of the contractor costs can be shared among the three units and thus the predictions would tend to be higher than the actual costs. On the other hand, to predict the cost of the control devices as though they were one large baghouse overemphasizes the economy of scale savings and would tend to underpredict the costs. Therefore both cases are presented with the understanding that the best prediction should lie between these extremes. (However this is not necessarily true.)

At first glance the results of the detailed comparison do not look very good; however, some of the discrepancies can be rationalized. In the case of the Nucla baghouse, the results actually look quite good. With the exception of the insulation costs, all of the equipment costs agree within 25 percent. Considering the excellent agreement between the actual and predicted costs of insulation in Tables 3, 5, and 6 it is possible to conclude that the Nucla baghouses might be underinsulated. This conclusion is supported by the observation that ". . . not enough insulation was installed on top of the baghouse. This has caused excessive heat loss and cool spots. Corrosion has been observed . . . ."[7] In spite of this discrepancy between reported and predicted values of insulation cost, the total field costs agree very well. The discrepancy between reported and predicted turnkey costs is attributable almost wholly to the order of magnitude difference in contingency costs. The reason for this discrepancy lies in the assumption that contingency costs would be

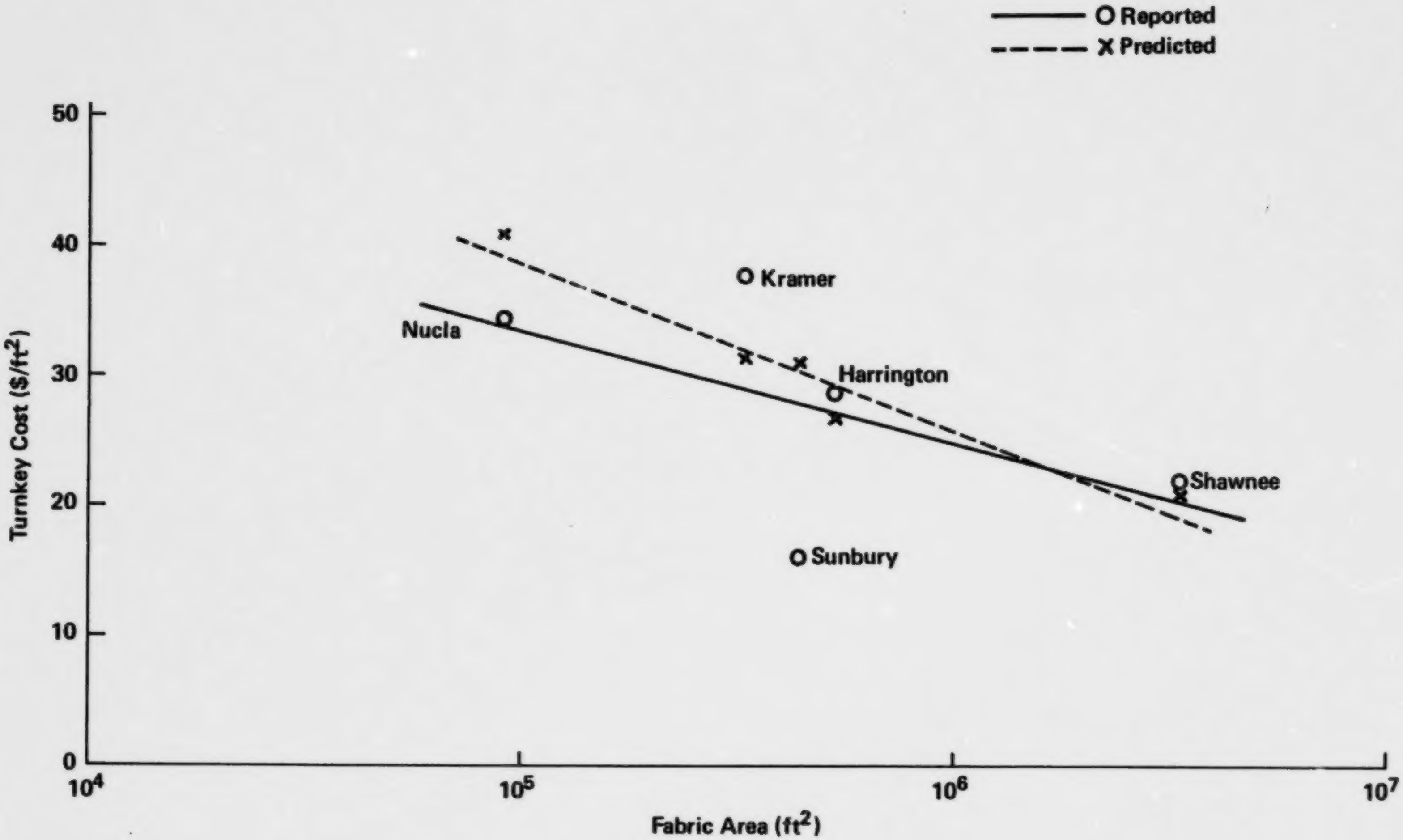


Figure 3. Economy of scale for predicted and actual turnkey costs (1978 dollars) of fabric filters.

equal to 20 percent of the total field cost. Considering the lack of any a priori method of calculating this type of cost, it is best to err toward the conservative.

The Kramer Station fabric filter is presented in Table 3. Here the models seem to grossly underpredict the cost of the collector and supports, and ducting and supports categories while the remainder of the accounts seem to agree reasonably well. In this comparison it is important to remember that the baghouse is a retrofit unit. It is possible that the assumption of 10 percent retrofit costs is too low, especially considering that the baghouse was constructed above existing railroad lines and probably required a large amount of structural steel. The contingency appears to be predicted high; however, this compensates slightly for the discrepancy between collector costs and, overall, the turnkey costs agree within ±25 percent.

The next unit to be considered is the Sunbury baghouse. In this case there are no ready explanations of the glaring discrepancies between actual and predicted values. The predicted cost of the baghouse is high, the predicted cost of the ash removal system is low, and the miscellaneous charges are high. The overpredictions are especially bewildering in light of the fact that this is a retrofit unit. One useful observation is that this baghouse was constructed within the shell of a stripped ESP. The benefit of this salvage seems to be unaccounted for because Cass and Bradway[8] report a salvage credit of only $3,000. For the turnkey cost both the predicted engineering and contingency costs are high. This is also somewhat surprising, considering that the Sunbury baghouse was the first one installed on a utility boiler. If anything, one would expect high engineering and contingency costs for any first-time installation. Either these costs never materialized at the Sunbury plant or they were not reported properly.

The George Neal plant (Table 5) uses a coldside, European design, electrostatic precipitator. The ESP cost model works well for predicting the cost of collector and supports, ash removal system, and insulation; however, the cost of ducting and supports and the miscellaneous costs are overpredicted. The source of these discrepancies is unknown. In spite of these differences, the total field costs agree within 25 percent. In calculating the turnkey cost, the assumed high cost of engineering was overconservative and the bottom-line reported cost is actually 66 percent of the predicted value.

The Navajo precipitator (Table 6) is a hotside unit. Here wide deviations of the reported costs from the predicted costs are seen. The predictions of collector and supports and ash removal system are very low and the prediction of miscellaneous costs is very high. It is possible that some of the costs reported under collector and supports are accounted for elsewhere in the model; for example, in the ducting and supports and miscellaneous costs. Similarly, some of the reported cost of the ash removal system may be accounted for in the predicted miscellaneous cost. In spite of these large differences, the reported and predicted total field costs agree very well. Even with the large discrepancy between the reported and assumed contingency costs, the turnkey costs also agree very well.

Though there are a few discrepancies unaccounted for between the model predictions and reported cost values, it appears that the models are capable of predicting overall project costs to within ±25 percent. For those cases when the model predictions fall outside of the ±25 percent range, they err to the conservative side (overprediction).

The economy-of-scale comparisons offer another perspective on the ability of the baghouse model to predict costs. In both Figures 2 and 3, the slope of the best fit line of the predicted costs is steeper than the slope of the best fit line of the reported values. This may indicate over-optimistic predictions of economy of scale. However, the poor values of correlation coefficents for the reported-cost-lines mean that the best fit lines are poor representatives of the reported costs. That is, no meaningful comparison can be made between reported and predicted economies-of-scale because the value derived from reported data is so poorly defined. This comment is true also for the question of whether or not a dollars-per-square-foot estimation is more reliable than a dollars-per-kilowatt estimate. More data are needed to clarify these questions.

In light of these comparisons, it is reasonable to conclude that the COST program is capable of predicting the cost of a particulate control system to within ±25 percent of the true cost. It is not expected that the COST program will ever be able to predict more accurately than this because of the assumptions inherent in the empirical models. For example, the models assume that labor rates will be the same from site to site although these costs actually vary from region to region. In addition, there are variations in design from one site to another that cannot be accounted for by the COST program. Another source of inaccuracy is the bidding process associated with capital-intensive air pollution control projects. The COST program makes a logical prediction of project costs based on design and operating information whereas there may be a subjective element introduced by the bidding process.

The accuracy and flexibility of a cost model depends on the number of assumptions made during development. By reducing the number of assumptions, a more accurate cost model can be developed. In a more detailed model the user would have to specify all of the inputs, but the predicted values would be more accurate. We recommend that this type of model be developed incorporating the useful input and output features of the current program. The extra amount of work required to run such a program would be more than outweighed by the accuracy of the results obtained. A more detailed model would also be more flexible. With this kind of a program, a researcher could determine whether or not a new concept in particulate control strategy could be cost competitive with existing technology. The present COST program has only limited flexibility in this respect.

In summary, the COST program is a useful tool to aid in the evaluation of different pollution control strategies. Like any tool, however, it can be misued. It is the user's responsibility to specify the design of the control device. Similarly, the user must consider factors such as depreciation and taxes in a complete evaluation of a project. However, if used properly, these models can simplify investment analysis.

SECTION 4

DESCRIPTION OF COST MODELS

4.1 OVERVIEW

The purpose of this section is to describe the models that have been developed to predict the annual capital cost and the total annual costs of ESPs, baghouses, and scrubbers. The equations for equipment and installation costs will be described first, followed by a description of the annual capital cost. Next, the annual operating and maintenance costs for the different systems will be described. This section on cost models will conclude with a discussion of the total annual cost.

4.2 CAPITAL COST ESTIMATION

The fastest and easiest way to estimate the capital cost of equipment of known size is to scale it according to the size and cost of an already existing unit of the same design. Williams[14] found that

$$C_b = C_a \left(\frac{S_b}{S_a}\right)^n \tag{4.1}$$

where

C_a, C_b = cost,

S_a, S_b = size factor (e.g., flow rate) and,

n = empirical exponent.

The accuracy of this technique depends on the accuracy of the exponent n which, in turn, depends on the cost and size values from which it is determined. The calibration data used to determine the exponents for the models described in this report were gathered from reports by Campbell et al., Ponder et al., and Kinkley and Neveril. These calibration data are actually a set of highly detailed cost estimates obtained in the following manner: " . . . each system was divided into approximately 30 component sections or accounts. The amount of material [required] was determined for each of these. Historical information was used to determine the man-hours of field labor required to erect or install this equipment. The purchase price of th material was based on [current] quotations for material with similar specifications. It is felt that this technique is sufficient to produce an estimate with absolute accuracy of -15% to +25% at the 90% confidence level."[2] This level of accuracy is retained when two or more of these "component sections" are added together and thus a predictive model can be simplified by grouping complementary "accounts" together. In this manner, the number of equations similar to (4.1) required to specify the whole system (and the number of exponents to be determined) can be reduced from 30 to 5 or 6. For instance, assume that the cost of an ESP including all controls and hoppers is known to within ±25 percent and that the cost of the steel required to support the ESP is known to within ±25 percent. By adding these two accounts together the number of exponents to be determined has been reduced by 1 with no loss of accuracy in the resulting estimate. Thus a small number of equations can be used to estimate the capital cost of a pollution control system with a relatively high degree of accuracy.[15]

In the following sections the models will be discussed in more detail. There are a few significant differences between the ESP/baghouse and the scrubber data bases: the ESP/baghouse data are from 1978 while the design and cost information for the scrubber is from 1973; the ESP/baghouse capital costs include installation labor and materials while the scrubber model has a separate multiplier for these costs. For these reasons, the equations that yield the capital costs of ESPs and baghouses will be described in one section and the equations for the scrubber model will be described in another.

No provision has been made for spare equipment to increase system availability. In other words, if the user desires to have a spare baghouse module in his baghouse, the baghouse must be overdesigned. For example, if the design calls for four baghouse modules with an air-to-cloth ratio of 2.0 ft/min and the user wants two spare modules to facilitate maintenance, then the design should be specified as having six modules with an air-to-cloth ratio of 1.33 ft/min.

4.2.1 ESP/Baghouse Capital Cost Models

Capital costs can be divided into two categories: direct and indirect. Direct costs include equipment, ducting, instrumentation, electrical and structural materials, insulation, site work, painting, and the associated cost of installation. Indirect costs include interest assessed during construction; contractors' fees and expenses; engineering, freight, and offsite expenses; and taxes, allowances, and contingencies.[3] The sum of the direct and indirect charges is called the total turnkey cost. Once the total turnkey cost has been determined, an annual capital cost can be determined. The reader is reminded that this is not the annualized cost, which is calculated as part of an investment analysis and is not considered here.

The following two sections will describe in detail the capital cost models for EPSs and baghouses.

4.2.2 ESP Cost Model

For the purposes of modelling, the total field cost was broken down into several accounts:

1. Collector and supports: includes the cost of the ESP and hoppers, hopper heaters, electrical hardware, a control room, and collector support steel.
2. Ducting and supports: includes the cost of the boiler outlet duct, ESP inlet and outlet nozzles, ID fan inlet duct, expansion joints, and the duct support steel.
3. Ash handling system: includes the cost of valves and a positive-pressure pneumatic ash-conveying system.
4. Insulation: includes the cost of insulation for the ESP and all ducting.
5. Other field cost: includes the cost of earthwork, concrete foundations, painting, and miscellaneous field charges.

Installation labor and material charges are included in accounts 1 through 4.

The equipment requirements for hotside and coldside are similar but the costs are different. The basic modelling equation predicts cost as a function of flow rate and specific collection area (SCA):

$$C_b = C_a \times \left(\frac{\text{flow rate}_b}{\text{flow rate}_a}\right)^f \times \left(\frac{\text{SCA}_b}{\text{SCA}_a}\right)^s \qquad (4.2)$$

The data used to evaluate the values of the exponents f and s for each of the accounts above are from the report by Campbell et al.[2] Table 7 lists the base case cost and the values of the exponents f and s for a coldside ESP. Values of the base case costs and the exponents f and s for a hotside ESP are listed in Table 8. Besides the differences in design of the collectors themselves, the only differences between the hotside and coldside systems are: (1) the hotside ESP has 4 inches of calcium-silicate block insulation while the coldside unit has only 3 inches; and (2) the ash diffuser system was not considered necessary for the hotside ESP. The reader is referred to the report by Campbell et al. for the complete design specification.

Chapman et al.[15] found these model parameters to be unsatisfactory for small (industrial-scale) collector systems. Since there is not enough detailed cost information to allow determination of the individual account parameters for ESPs with inlet flow rates of less than 350 m^3/s (@ 150° C), a separate equation was developed for modelling the total field cost of those systems. The equations are of the same form as Equations 4.1 and 4.2 except there is a single equation that yields the total field cost. The base case costs and the values for the exponents f and s for small hotside and coldside ESPs are shown in Table 9.

After the total field cost has been estimated with one of the above models, the total installed cost is determined by adding the cost of contingencies and engineering and fee to the total field cost. The contingency charge is included to account for unforeseen expenses. It does not include escalation. The engineering charge accounts for prime contractor engineering and fee. These costs are estimated as a fixed percentage of the total field cost; typically 20 percent.

4.2.3 Fabric Filter Cost Model

Like the ESP cost model, the baghouse cost model consists of a set of accounts that, when added together, yield the total field cost of the particulate control system. The accounts are:

TABLE 7. MODEL PARAMETERS FOR A COLDSIDE ESP

Account	Base case cost[a] (× 10^6)	f	s
Collector and supports	4.724	0.97	0.94
Ducting and supports	3.134	0.83	0
Ash system	0.703	0.78	0.72
Insulation	0.943	0.97	0.34
Other field charges	3.554	1.02	0.74

[a] Base case flow rate: 929.74 m^3/s @ 150° C, 709 mm Hg.
Base case SCA: 68.89 $m^2/m^3/s$.

TABLE 8. MODEL PARAMETERS FOR A HOTSIDE ESP

Account	Base case cost[a] (× 10^6)	f	s
Collector and supports	7.235	0.97	0.94
Ducting and supports	3.705	0.94	0
Ash system	0.582	0.75	0.76
Insulation	1.523	0.87	0.47
Other field charges	8.114	1.05	0.53

[a] Base case flow rate: 1,245.94 m^3/s @ 371° C, 721 mm Hg.
Base case SCA: 78.74 $m^2/m^3/s$.

TABLE 9. MODEL PARAMETERS FOR SMALL ESPS

Account	Base case[a] total field cost (× 10^6)	f	s
Coldside ESP	10.814	0.74	0.60
Hotside ESP	17.424	0.77	0.58

[a] Base case flow rates and SCAs are the same as in Tables 7 and 8.

1. Collector and supports: includes costs for the baghouse and hoppers, support steel, control room, inlet and outlet manifold, bypass dampers and duct, reverse-air fans, and hopper heaters.
2. Ducting and supports: includes costs for the boiler outlet duct, the ID fan inlet duct, expansion joints, and the duct support steel.
3. Ash handling system: includes cost of valves for each hopper and the cost of a positive-pressure pneumatic ash-conveying system.
4. Insulation: includes cost of insulation for the baghouse, reverse-air fans, and all ducting.
5. Other field charges: includes the cost of earthwork, concrete foundations, painting, and a contingency cost for the ID fan.

Accounts 1 through 4 include the cost of installation labor and materials.

The cost modelling equation for fabric filters is based on flow rate, air-to-cloth ratio, and the number of baghouse modules. The general equation is:

$$C_b = C_a \times \left(\frac{\text{flow rate}_b}{\text{flow rate}_a}\right)^f \times \left(\frac{ac_b}{ac_a}\right)^a \times \left(\frac{\text{modules}_b}{\text{modules}_a}\right)^m \tag{4.3}$$

The values of the base case costs and the exponents f, a, and m have been determined from data contained in the report by Campbell et al. (Ref. 1, pp. II-28 to II-40) and are presented in Table 10.

The total field cost is the sum of the acounts in Table 10. The total installed cost is calculated by adding contingency and engineering charges to the total field cost as described above for precipitators.

4.2.4 ID Fan Cost

The induced draft (ID) fan cost is dependent on the flue gas flow rate and the maximum pressure drop across the control device. Unlike the cost of collector systems, there is no economy of scale when purchasing these fans. The following equation has been adapted from data reported by Ponder et al.:[3]

$$\text{fan cost} = \$80/\text{hp} \times \text{fan hp} \times 1.495 \times 1.2 \times \frac{215}{148.2} \ . \tag{4.4}$$

TABLE 10. MODEL PARAMETERS FOR FABRIC FILTERS

Account	Base case cost[a] ($\times 10^6$)	f	a	m
Collector and supports	5.914	0.70	-0.70	0.22
Ducting and supports	0.827	0.72	0	0
Ash system	0.553	0.69	0	0.39
Insulation	1.550	0.61	-0.54	0.31
Other field charges	4.068	0.77	-0.47	0.22

[a] Base case flow rate: 929.74 m^3/s @ 150° C, 709 mm Hg.
Base case air-to-cloth ratio: 0.55 m/min.
Base case number of modules: 16.

This cost includes an indirect cost multiplier of 1.495 (see Glossary for a complete definition) and a 20 percent contingency multiplier. The value of \$80 per horsepower is in December 1973 dollars (CE Plant Cost Index = 148.2).[16] To make the fan cost consistent with the collector system costs, it is updated to December 1978 dollars (CE Plant Cost Index = 215).

4.2.5 Ash Pond Cost

The cost of the ash pond is dependent on its size, which is determined by the amount of ash collected. This cost is also dependent on the presence or absence of a flue gas desulfurization (FGD) unit in the pollution control system. If an FGD system is included, a larger pond will be required for ash disposal; however, because of a generous economy of scale, the unit cost will be lower. Only the portion of the ash pond needed for disposal of the ESP or baghouse fly ash is assigned to the control device for costing purposes. The amount of ash collected is the product of the amount of ash generated times the efficiency of the collector. The amount of fly ash generated in the boiler is calculated by:

$$\text{ash generated} = \frac{\text{fraction fly ash} \times \text{boiler size}}{\text{coal heat value} \times \text{steam cycle efficiency}} \tag{4.5}$$

where

fraction fly ash = fraction of ash in coal that leaves boiler in flue gas,

boiler size = net generating capacity,

coal heat value = unit energy per unit mass,

steam cycle efficiency = thermodynamic efficiency of energy conversion.

The amount of ash generated is calculated assuming 100 percent capacity; however, the pond size is calculated for the actual capacity factor:

$$\text{pond size} = 8.267 \cdot 10^{-2} \times \text{ash collected} \times \text{capacity factor} \qquad (4.6)$$

This equation yields pond size (acre-ft) assuming a pond life of 30 years. The constant 8.267×10^{-2} acre-ft/kg/h is derived from data reported by Ponder et al. The cost of the pond is calculated from the equation:

$$\text{actual pond cost} = 13648 \times (\text{pond size})^{0.583} \qquad (4.7)$$

Equation 4.7 was derived from data in the report by Ponder et al. (Ref. 2, p. B-50) and includes the costs of land, excavating, and diking but does not include any charges for indirect costs or contingencies. The constant 13648 in Equation 4.7 is the cost in dollars of a pond with 1 acre-ft of volume. These costs must be included to put the pond cost on the same basis as the equations for the ESP and baghouse model. The pond cost is adjusted for these factors in the following equation:

$$\text{total pond cost} = \text{actual pond cost} \times 1.395 \times 1.2 \times \frac{215}{148.2} \qquad (4.8)$$

where 1.395 is an indirect cost multiplier, the 1.2 is for a 20 percent contingency, and the ratio 215/148.2 is included to update the cost from December 1973 dollars (i.e., year of estimate) to December 1978 dollars as in the example of the ID fan cost (Section 4.2.4). The indirect multiplier in Equation 4.8 is less than the one used for the ID fan because the cost of the ash pond is mostly for labor; hence, some of the overhead, freight, and insurance charges can be eliminated.

4.2.6 Turnkey Costs

The turnkey cost in 1978 dollars for an ESP or baghouse is the sum of the costs of the installed equipment, the ID fan, and the ash pond. This turnkey cost is updated to current dollars by multiplying by the ratio of the current CE Plant Cost Index to the December 1978 value (215).

4.3 SCRUBBER CAPITAL COST MODEL

The cost model for venturi scrubbers is very different from the models for ESPs and baghouses. The fundamental difference between the models has to do with the accounting of installation charges in the ESP and baghouse models. In the venturi scrubber model, the costs of individual items are estimated first and added together to yield the total equipment cost, then the total capital cost is calculated by adding direct and indirect costs to the total equipment cost. The scrubber model is also designed to include or delete certain costs depending on whether or not the scrubber is an integral part of a flue gas desulfurization (FGD) system. The items included in a complete scrubber system are venturi modules, ducts, holding tanks, agitators, pumps, heat exchangers, soot blowers, ID fan, clarifier, and ash pond. A separate modelling equation is used to determine the cost of each item. These costs are calculated in December 1973 dollars based on data reported by Ponder et al.[3] and Kinkley and Neveril.[4] All of the numerical constants appearing in this section are derived from data included in those reports. After the total capital cost is calculated, the CE Plant Cost Index is used to update the system cost to future dollars.

The cost of the venturi modules is estimated assuming a maximum size of 175 m^3/s (51.7° C, saturated) and equal flow rate through all the modules. The cost of a single module is a function of the gas flow rate and the pressure drop across the module. These factors are included in the module cost multiplier:

$$\text{cost multiplier} = 1.35 \times (\text{mod flow})^{-0.138} + 6.1753 \cdot 10^{-5} \times \Delta P_{\text{venturi}} \times (\text{mod flow})^{1.242} \tag{4.9}$$

where the module flow rate is in m^3/s, $\Delta P_{\text{venturi}}$ is in cm of H_2O, and the cost multiplier is dimensionless. The module cost is then calculated according to the formula:

$$\text{module cost} = \$1{,}590/\text{m}^3/\text{s} \times \text{cost multiplier} \times \text{mod flow} \quad . \tag{4.10}$$

The total module cost is the sum of the costs of all the modules.

The duct cost per venturi module was found to be dependent on the number of modules in the system and the flow rate per module. The general form of the equation for calculating duct cost is:

$$\text{duct cost} = \text{base case cost} \times (\text{mod flow})^m \tag{4.11}$$

The values of the base case cost and the exponent m for various system sizes are given in Table 11. The cost of all ducting is the product of the duct cost per module times the number of modules.

The cost of bypass valves for each module is estimated assuming a cost of \$278/m^3/s. The cost for all bypass valves is the sum of the costs for each module.

It is assumed that one rubber-lined holding tank, with a retention time of 5 minutes, is required for each module. When tank size is expressed in cubic meters, the tank cost can be estimated with the following equation:

$$\text{holding tank cost} = 809 \times (\text{tank size})^{0.643} \tag{4.12}$$

scaled from a cost of \$809 for a tank with 1 cubic meter of volume. The cost of agitators for each holding tank is estimated assuming a cost of \$2,000 per 100-m^3 tank capacity. The pumps to be used in conjunction with each tank are assumed to have a capacity no larger than 0.631 m^3/s (10,000 gal/ min) and are all the same size. There will be one spare pump for each holding tank. With

TABLE 11. MODEL PARAMETERS FOR DUCT COST PER MODULE

No. of modules	Base case cost	m
1	1,011	0.50
2	1,695	0.50
>2	2,577	0.46

these assumptions, the pump cost is calculated as:

$$\text{pump cost} = 19607 \times (\text{pump flow rate})^{0.457} \quad . \qquad (4.13)$$

This value is scaled from a cost of \$19,607 for a slurry flow rate of 1 m^3/s. The total investment for all holding tanks, agitators, and pumps is the cost per module times the number of modules.

It is assumed that one soot blower is required for each venturi train in the scrubber system. The cost of each soot blower is estimated according to the equation:

$$\text{soot blower cost} = 1475 \times (\text{mod flow})^{0.696} \qquad (4.14)$$

(i.e., \$1,475 for a flue gas flow rate through the venturi module of 1 m^3/s.) The cost for all blowers is the sum of the costs for each module.

Heat exchangers are required to provide 28° C reheat to the flue gas. The cost in December 1973 dollars is \$636/m^3/s. Fan costs are based on the volumetric flow rate of the reheated gas. The cost varies linearly with horsepower at \$80/hp.

The cost of clarifiers in the scrubber system depends on whether or not the venturi train is part of an FGD system. The general form of the cost modelling equation for clarifiers is:

$$\text{clarifier cost} = \text{base case cost} \times (\text{ash quantity})^{c} \quad . \qquad (4.15)$$

The ash quantity in Equation 4.15 is simply the amount of dry ash collected per hour. Details on the calculation of this value are given in Section 4.2.5. The values for base case cost and the exponent c for the cases when the clarifier is also fed by an FGD system are shown in Table 12. The values of these model parameters for the cases when the clarifier is independent of an FGD system are shown in Table 13.

TABLE 12. COST OF A CLARIFIER AS AN INTEGRAL PART OF AN FGD SYSTEM

Ash quantity (kg/h)	Base case cost	c
0 - 26,670	146.5	0.63
>26,670	333.7	0.63

TABLE 13. COST OF A CLARIFIER INDEPENDENT OF AN FGD SYSTEM

Ash quantity (kg/h)	Base case cost	c
0 - 45,360	1,554	0.47
45,361 - 90,720	2,338	0.47
90,721 - 136,080	2,783	0.47
>136,080	3,308	0.47

A complete venturi train includes all of the above items. For the purposes of modelling the cost of a venturi train when it is an integral part of an FGD system, however, certain items can be assigned to the FGD system. These items include the heat exchangers, soot blowers, ducts, and valves. Consequently, the costs of these items are deleted from the cost of the venturi train when the venturi train is part of an FGD system.

The total direct cost of the venturi scrubber train is calculated by adding all of the equipment costs and multiplying their sum by factors for installation labor and materials. The materials cost accounts for foundations, steel work for supports, piping for effluents, instrumentation, insulation, and painting. Labor charges of 80 percent and material costs of 60 percent of the total equipment cost are typical.[2]

The cost of the ash pond for the venturi scrubber system is calculated as described above for ESPs and fabric filters with the exception of the cost multipliers for indirect and contingency charges and the CE Plant Cost Index factor. These multipliers are not included in the estimate for the ash pond cost in the venturi scrubber model because they are accounted for elsewhere.

Indirect expenses for the purchase and installation of the scrubber system are estimated to be 49.5 percent of the total direct cost plus 39.5 percent of the ash pond cost. Contingency costs are estimated as a percentage of direct, indirect, and pond costs.

4.3.1 Turnkey Cost

The total turnkey cost in December 1973 dollars is the sum of the direct, indirect, contingency, and pond costs. Cost scaleup to current dollars is accomplished with the CE Plant Cost Index.[16]

4.4 ANNUAL CAPITAL COST

The annual capital cost as defined here includes only the annual payment of principal and interest for the money borrowed to finance the project. This is not intended to include other criteria such as salvage value, depreciation, taxes, etc. The annual capital cost as described here may be used as input to an investment analysis. It is not advisable to use the annual capital cost as an absolute measure of merit.

The capital recovery factor is used to determine the annual payment of principal and interest. This payment is calculated according to the formula:

$$A = P \times \frac{i(1+i)^N}{(1+i)^N - 1} \qquad (4.16)$$

where

A = annual payment,

P = total turnkey cost,

i = annual interest rate, and

N = life of the equipment.

The total annual cost can then be calculated as the annual payment for capital equipment plus the annual operating and maintenance costs.

4.5 OPERATING AND MAINTENANCE COSTS

This section describes the methods used to calculate the operating and maintenance costs for each particulate control system. To a large degree, the costs can be divided into three categories: operating labor and materials (excluding electricity), maintenance labor and materials, and electrical requirements. To ensure uniformity in calculations, all costs are computed assuming operation at 100 percent capacity. These costs are then added and corrected to the actual capacity factor. It is assumed that there is no commercial value for the collected fly ash. Another simplifying assumption has been made concerning the cost of operating labor. Campbell et al. (p. III-18)[2] reports that the annual cost of labor to operate an ESP or baghouse associated with a 500-MW boiler running at full capacity is $20,000. Similarly, the annual cost of operating labor for the ash removal system is reported as $60,000. Since these costs are relatively low compared to annual capital and maintenance costs, it is assumed that they are independent of size or operating capacity. Any error caused by this assumption is within the expected overall accuracy of ±25 percent.

No other generalizations about operating or maintenance costs have been made, so the remaining details of the cost estimation procedures will be described below in a separate section for each device (ESP, baghouse, and scrubbers).

4.5.1 ESP Operation and Maintenance

The operating cost for an ESP includes the cost of labor, which has been described above, and the cost of electricity, calculated as the sum of the electrical requirements times the electric rate ($/kW). In a hotside precipitator system, the transformer-rectifier (TR) sets of the ESP, the ash removal system, accessories, and the ID fan require electricity. A coldside precipitator may have additional electricity requirements because of the hopper heaters, which are not needed for a hotside ESP. The power required by the TR sets is determined by the operating point on the voltage-current curve, the current density, and the total plate area in the following manner:

$$\text{TR set kWh} = \text{TR kV} \times \text{plate area} \times \frac{\text{current density}}{0.6} \quad . \qquad (4.17)$$

The constant 0.6 is the assumed efficiency of a.c. to d.c. conversion. Electrical requirements for the accessories and ash maintenance system are also based on plate area. The unit requirements for these items are listed in Table 14.

Duty factors are used to adjust these power requirements to account for the fact that the accessories and ash removal system do not work all the time that the precipitator is operating. The power requirements of the ID fan depend on the flow rate, the pressure drop, the fan efficiency, and the load

TABLE 14. ELECTRICAL REQUIREMENTS PER UNIT AREA FOR ACCESSORIES AND ASH HANDLING SYSTEM

Type	Accessories kW/10^6 m^2	Ash system kW/10^6 m^2
Coldside	$3.229 \cdot 10^{-3}$	$7.788 \cdot 10^{-3}$
Hotside	$3.229 \cdot 10^{-3}$	$5.097 \cdot 10^{-3}$

factor. After the required horsepower has been calculated, it is a simple unit conversion problem to determine the number of kilowatt-hours required. The electrical requirements for hopper heaters are estimated by assuming that one hopper is required for every 1,335 m^2 of plate area with one heater in every hopper. The total power requirement is the product of the number of hoppers times the power requirement per hopper times the heater duty factor.

The only maintenance costs in an ESP system are those for upkeep of the ESP, the ash handling system, and the ash pond. Maintenance costs for the ESP and ash handling system are estimated based on the plate area. Unit costs for both hotside and coldside ESPs are listed in Table 15.

Annual pond maintenance costs are estimated as a percentage of the capital cost of the pond and are calculated to include overhead charges.

4.5.2 Fabric Filter Operation and Maintenance

As with the ESP, the operating cost of a fabric filter includes labor and electricity. The items requiring electricity in a fabric filter system are

TABLE 15. UNIT MAINTENANCE COSTS FOR PRECIPITATORS

Type	ESP \$/m^2	Ash system \$/m^2
Coldside	0.769	0.308
Hotside	0.769	0.923

the ID fan, the hopper heaters, the reverse-air fans, accessories, and the ash removal system. The power requirement for the ID fan is calculated from the gas flow rate, pressure drop, fan efficiency, and load factor. The hopper heater power is based on a requirement of 15 kW per heater with one heater in every hopper and one hopper in every module. The power requirement for the reverse air fans must be supplied by the user on a basis of tens of thousands of kilowatts per square meter of bag area. The number of kilowatt-hours required for accessories and the ash removal system are estimated assuming power requirements of $2.153 \cdot 10^{-3}$ kW/m^2 bag area for the accessories and 0.557 kW/m^2 bag area for the ash system. These numbers are then adjusted with the appropriate duty factors.

The most significant maintenance cost for baghouses is the purchase and replacement of bags. The average life of a bag is estimated by:

$$\text{bag life} = \frac{\text{bag life constants}}{(\text{air-to-cloth}/0.61\ \text{m/min})^{b}} \tag{4.18}$$

The bag life constant is the life of the bag when the air-to-cloth ratio is 0.61 m/min. The exponent b is an empirical constant reported by Chapman et al.[16] to have a value of 0.6. When the bag no longer performs satisfactorily, it must be replaced. This maintenance is usually performed at regularly scheduled intervals. The materials charge for this maintenance includes the cost to replace all of the bags in a given compartment and the overhead charge for procurement. The labor charge is based on the hourly labor rate, the amount of time per unit area required to replace the bags, and the total area to be replaced. These costs are usually averaged over the life of the bags.

It is not uncommon that a bag (or bags) will need replacing before a scheduled time. The cost for this type of maintenance will be more expensive because of the extra time required to locate the specific bag (or bags) that must be replaced. It is a good idea to include a contingency for this situation in the form of an estimated fraction of bag failures per year. The cost of the bags and labor for this unscheduled maintenance is added to the yearly cost for scheduled bag replacements to yield the total bag-related maintenance cost per year.

Other than the maintenance required for bag replacement, there are also maintenance costs for the ash pond, the ash removal system, and for nonbag items associated with the baghouse, such as pumps, valves, and other ancillary equipment. The larger the baghouse, the more equipment there will be to service. Consequently, the cost of nonbag maintenance labor is based on the total flow through the system. It is assumed that the cost of materials for this maintenance will be about the same as the cost of labor.

The cost of maintenance for the ash removal system is based on the total gas flow rate and the number of modules in the system. It has been reported that the cost of maintaining an ash handling system on a baghouse with 16 modules is $\$25.5/\text{m}^3/\text{s}$ of gas flow. The cost for a system with a different number of modules is directly proportional to this number. Ash pond maintenance cost for a baghouse is estimated in the same way as for an ESP.

4.5.3 Scrubber Operation and Maintenance

Operating costs for scrubbers are higher than the costs for precipitators and baghouses because of the process materials required. Process materials include water, steam, and electricity. The annual cost of water is determined by the liquid-to-gas ratio, the gas flow rate, and the unit cost of water ($\$/\text{m}^3$). Steam cost is estimated assuming a requirement of 0.1341 $(\text{GJ/h})/(\text{m}^3/\text{s})$ for reheat. The person using the program is expected to supply the unit costs for water ($\$/\text{m}^3$) and steam ($/GJ). Items requiring electricity in a scrubber system include the clarifiers, the pumps, and the ID fan. It is assumed that the clarifiers consume 0.013 hp/kg/h of dry ash collected. Pumps that are 100 percent efficient are expected to require 400 hp/m^3 of water flow against a 100-ft head. The power requirement of a real pump is determined by correcting the ideal value for the actual efficiency of the pump.

It is easiest to estimate the annual cost of maintenance for a scrubber system as a fraction of the capital cost of the system. The user can supply his own value for this fraction or use the default value in the program. This cost is also calculated to include a 50 percent overhead charge.

4.6 TOTAL ANNUAL COST

Once the annual capital and operating expenses are known, the total annual cost can be calculated by summing the annual capital cost and the operating and maintenance costs corrected to the actual time-capacity factor for the plant.

SECTION 5

USER INSTRUCTIONS

This section describes in detail several items specific to the task of executing the COST program to predict particulate control system costs. The computer system required is described first, followed by some helpful instructions for the person who has never worked with a TRS-80®. The final section presents a thorough example of program execution with complete step-by-step instructions for the user. Other useful information about the mechanics of the COST program is given in Section 6 and Appendixes C and D.

5.1 SYSTEM REQUIREMENTS

The COST program was written on a Radio Shack Level II, Model I TRS-80® microcomputer with 48 kilobytes of available memory and two 5-1/4-in. floppy disk drives. This program can also be run on a system with only one disk drive. The program requires either the TRSDOS® or NEWDOS® Disk Operating System (DOS) or any other DOS that is capable of running Microsoft Disk Basic and is file-compatible with TRSDOS. The COST program is also designed to provide a listing of results on a line printer (e.g., Radio Shack Line Printers I or IV). It is desirable to have all of the computer equipment plugged into a single, switched outlet strip so that everything can be turned on at once. If you have two or more disk drives in your system we recommend that you put the COST program on a write protected disk along with a DOS. Use an empty (but formatted) diskette to store the data from the program.

5.2 A WORD ABOUT FLOPPY DISKETTES

In the past there has been a lack of information about floppy diskettes. Unfortunately, this void could only be filled through experience. Based on this experience, the following precautions are offered to the users:

1. NEVER turn the computer ON or OFF while a diskette is in a drive.

2. Always make backup copies of programs and data files. Keep copies in a safe place.

3. Keep diskettes away from magnetic field sources such as telephones. Keep diskettes in their protective jackets when not in use.

4. Never remove a diskette from a drive while the program is running. If the program ever stops executing abnormally (i.e., because of an error or because the BREAK key was hit) use the BASIC command CLOSE to guarantee that all disk files are closed properly.

5.3 FIRST-TIME USER

The advantage of microcomputers is that they are very easy to use. Past experience with computers has little or no bearing on one's ability to operate the TRS-80 microcomputer; however, a certain amount of preparation is required before running the COST program. Read over all of these instructions before you turn on the computer.

The heart of any sophisticated computer system is its operating system; in this case a Disk Operating System (DOS). The operating system is a monitor program: it does all of the housekeeping chores and silently "waits in the wings" until it has another job to do. All programs (including the COST program) rely on the DOS to handle simple operations. The DOS accepts commands and moves information between the disk drives, memory, and printer. Since you are a beginner, we will work with Radio Shack's TRSDOS. Read the TRSDOS & DISK BASIC Reference Manual.[17] This manual contains well-written instructions on how to turn on your computer, how to enter commands, and how to run programs. If the power cords of your Model I TRS-80 are not plugged into an outlet strip, then be sure to read over the instructions for the power-up sequence on pages 2 through 8 of the DOS reference manual. Pay particular attention to the descriptions of the DOS commands BACKUP, DIR, and COPY. Read over their descriptions and practice using them. DO NOT use your COST program diskette for practicing. When you are comfortable with these commands, make a BACKUP copy of the COST program. It is a good idea to store the original COST program diskette in a safe place and use it ONLY to make new backup copies as needed. Familiarize yourself with the RESET button, it is really a PANIC button: When all else fails, press the RESET. Note that when you press the RESET, your program and data will be lost from memory. The RESET does not affect anything stored on your diskettes. Pressing RESET is often called BOOTing the system because the operating system is read from the disk (boot strapped) by a small program in the computer's read only memory.

After becoming more familiar with the DOS commands, look over the DISK BASIC chapter of the DOS manual. The COST program is written in DISK BASIC and you will need to be at least somewhat familiar with it. For now you only need to study the Introduction and the description of the RUN command (pp. 7-31). In the future, the LOAD, LIST, EDIT, KILL, and SAVE commands may be useful as well as the LEVEL II BASIC Reference Manual.[18]

The reference manuals for the TRS-80 Model III microcomputer contain essentially the same information as the manuals for Model I. Model III users should refer to the appropriate sections of their manuals for instructions on how to use DOS and BASIC commands.

5.4 SAMPLE SESSION OF COST PROGRAM EXECUTION

The best way to learn how to use the COST program is to step through a complete example of program execution. Let's say, for example, that we are interested in comparing the costs of a hotside and a coldside ESP operating on the same boiler. The first step in running the program is to gather information on the plant and the control device and fill in the input worksheets. A sample woksheet that lists the default values for plant parameters is shown in Figure 4. Input worksheets for each control device are included in Appendix E. Usually the design and operating information required by the COST program would be obtained from a computer model for the control device such as the SoRI or RTI precipitator models.[19] [20] Computer models are also available for predicting the performance of fabric filters[21] and venturi scrubbers.[19] For the purposes of this illustration we will simply use the default case values for the most of the parameters. Figure 5 is a simplified flowsheet of the COST program. The first step in program execution is to input the plant, coal, economic, and emissions data. From this information, the program will do some preliminary calculations and then save all of the input data onto a diskette. Next you will be asked which control device you would like to evaluate.

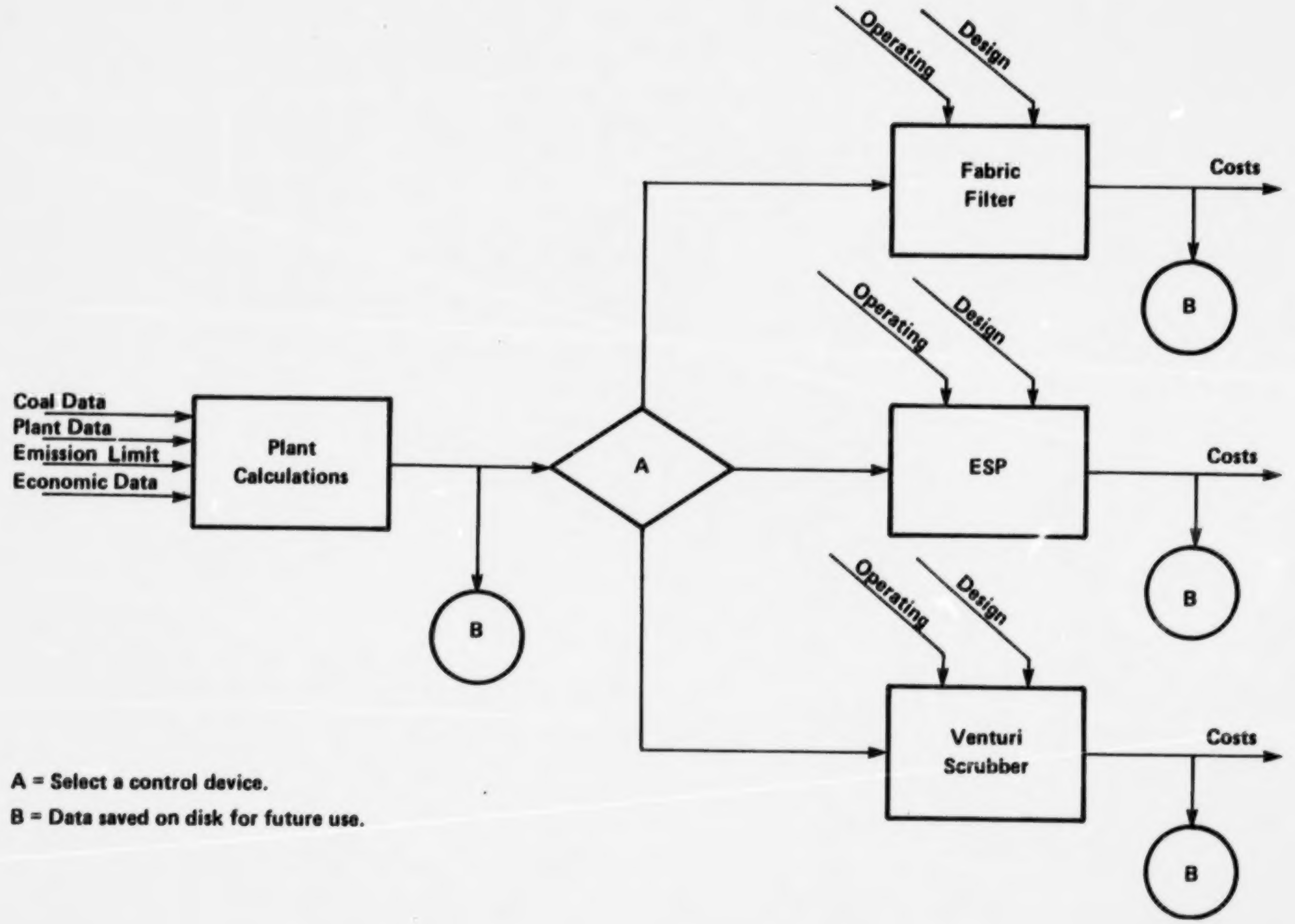
PLANT INPUT WORKSHEET

Plant: Test
Date: 6/12/81
Remarks: Demonstration of the COST program

PLANT DATA

Boiler size	500	MW net			
Capacity factor	70	%			
Chemical Engineering Plant Cost Index	270				
Emission limit	43	ng/J	or		lb/MBtu
Plant altitude	300	m	or		ft
Interest rate	15	%/yr			
Cost of electricity	30	mil/kWh			
Contingency as percent of field cost	20	%			
Engineering as percent of field cost	20	%			
Steam cycle efficiency	38	%			
Coal heating value	23,240	kJ/kg	or		Btu/lb
Fraction excess air	0.25	%			
Percent carbon in coal	60	%			
Percent hydrogen in coal	5.4	%			
Percent oxygen in coal	11.2	%			
Percent sulfur in coal	0.6	%			
Percent nitrogen in coal	1.6	%			
Percent ash in coal	7.6	%			
Percent water in coal	13.6	%			

Figure 4. Plant input worksheet.


Coal Data
Plant Data
Emission Limit
Economic Data
Plant Calculations
B
A
Operating
Design
Fabric Filter
Costs
B
Operating
Design
ESP
Costs
B
Operating
Design
Venturi Scrubber
Costs
B

A = Select a control device.

B = Data saved on disk for future use.

Figure 5. COST program flow sheet.

Once the required device information has been entered, the program will estimate the capital and operating costs based on the plant and device information supplied. The results will be displayed on the video screen and saved on the diskette in the same file with the plant information. You can also request a hard-copy listing of the input and output parameters.

In the following description, anything that is printed by the computer will be underlined for clarity. When a key on the keyboard is referred to, it will be enclosed in brackets like this <1>.

After turning on the power and BOOTing (pushing RESET) the TRSDOS diskette, go into DISK BASIC by typing

```
DOS READY
BASIC <ENTER>
```

The DOS will find DISK BASIC on the diskette, load it into memory, and turn control over to the BASIC interpreter. The screen will clear and you will be asked HOW MANY FILES? PRESS <ENTER> and a value will be assumed. Next you will be asked MEMORY SIZE? Press <ENTER> again. The values that are assumed by the computer when you press <ENTER> will be sufficient for our purposes.

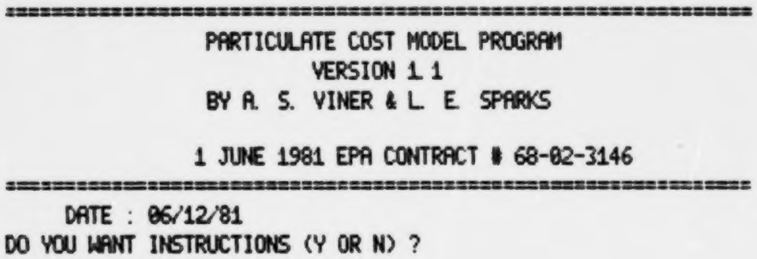
When BASIC responds with the READY message, type

```
READY
>RUN"COST"<ENTER>
```

The DOS will go get the program and load it into memory. After the program has been loaded, BASIC will begin execution. First the screen will clear and print a message as shown in Figure 6. The program is waiting for you to enter today's date in MM/DD/YY format, like this:

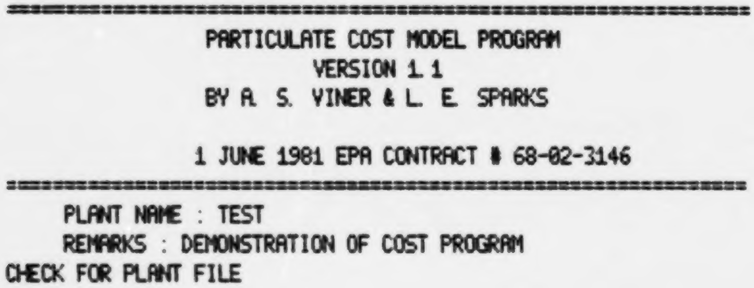
```
DATE : 06/12/81<ENTER>
```

The numbers will appear on the screen as you type them. After you press <ENTER>, the program will ask if you want instructions. If you answer with <Y>, the screen will clear and a message will appear on the screen with helpful information for program execution. After you have finished reading the instructions (or if you answered <N>), the screen will clear and the program will ask for the plant name as shown in Figure 7. Enter the plant name:



```
==============================================================
                  PARTICULATE COST MODEL PROGRAM
                           VERSION 1.1
                  BY A. S. VINER & L. E. SPARKS

               1 JUNE 1981 EPA CONTRACT # 68-02-3146
==============================================================
     DATE : 06/12/81
DO YOU WANT INSTRUCTIONS (Y OR N) ?
```

Figure 6. The beginning of the COST program.



```
==============================================================
                  PARTICULATE COST MODEL PROGRAM
                           VERSION 1.1
                  BY A. S. VINER & L. E. SPARKS

               1 JUNE 1981 EPA CONTRACT # 68-02-3146
==============================================================
     PLANT NAME : TEST
     REMARKS : DEMONSTRATION OF COST PROGRAM
CHECK FOR PLANT FILE
```

Figure 7. Identifying a plant and selecting units.

PLANT NAME:TEST<ENTER>

Next the program will ask for REMARKS. Type in any message and press <ENTER>. When you press <ENTER> the computer will print the message

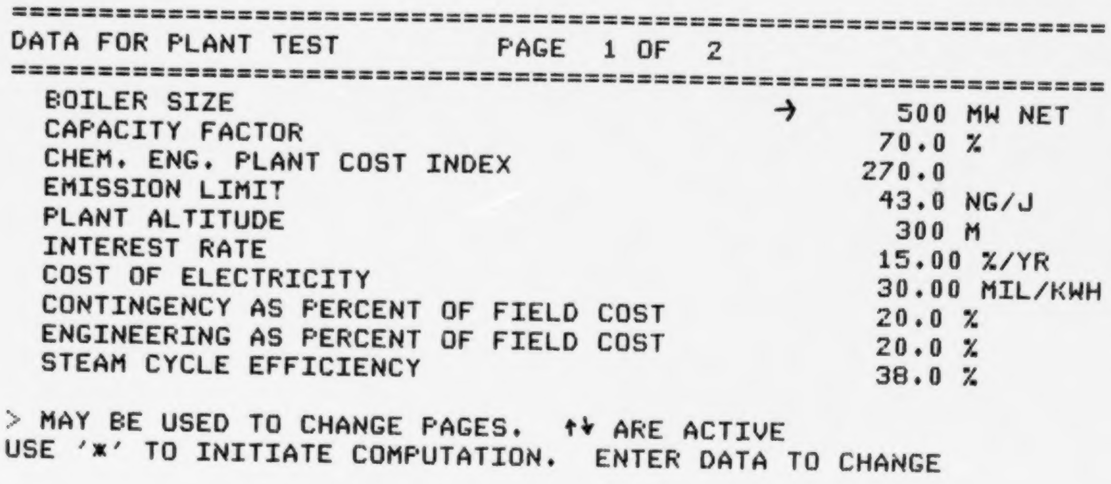
CHECK FOR PLANT FILE

and then search all the diskettes in the disk drives for a file containing data on that plant. Since the file hasn't been created yet, it won't be found. The program will then ask you if you wish to enter your data in English or metric units. Answer with <M>.

At this point, the program may pause, clear the video screen, and display a page of data. A page of data may be defined as the amount of data that can be displayed conveniently on the screen at one time. Figure 8 shows Page 1 of the plant data. This method of displaying data, with a description in the left column and a corresponding number in the right column is called the menu format. The numbers in the right column of Figure 8 are the default (or assumed) values for the items listed in the column on the left side of the screen. In executing the program you can either use the default values or enter your own values for various parameters. Look at all of the items in the left column. Most are self-explanatory; however, some may need clarification. A glossary of all of the terms contained on all the menu pages is contained in Appendix A. Let's say that all of the default values are sufficient for our purposes except the BOILER SIZE. Suppose we are interested in estimating the cost of the particulate control for a 150-MW boiler instead of a 500-MW boiler. Notice the arrow to the left of the 500. That means we can change the value. Type

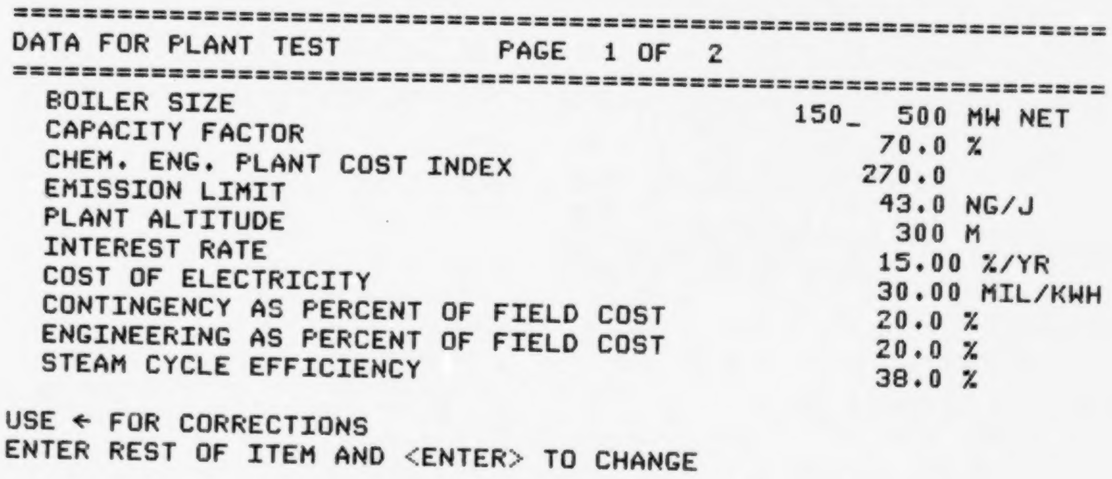
150<ENTER>

The numbers will appear to the left of the 500 as you type them in as shown in Figure 9. There is no need to enter the units associated with the number (e.g., MW). If you make a mistake when typing in a number, use the <←> key to backspace and then type the correct number as indicated by the message at the bottom of the screen. When you press <ENTER>, the screen will clear and the page will be displayed again. The number 150 will have replaced the value 500 to the right of BOILER SIZE. Also the arrow will have moved down to point at the number 70.0. Any number on the screen can be changed when the arrow



```
===============================================================
DATA FOR PLANT TEST          PAGE  1 OF  2
===============================================================
  BOILER SIZE                                      →      500 MW NET
  CAPACITY FACTOR                                        70.0 %
  CHEM. ENG. PLANT COST INDEX                           270.0
  EMISSION LIMIT                                         43.0 NG/J
  PLANT ALTITUDE                                          300 M
  INTEREST RATE                                         15.00 %/YR
  COST OF ELECTRICITY                                   30.00 MIL/KWH
  CONTINGENCY AS PERCENT OF FIELD COST                   20.0 %
  ENGINEERING AS PERCENT OF FIELD COST                   20.0 %
  STEAM CYCLE EFFICIENCY                                 38.0 %

> MAY BE USED TO CHANGE PAGES.  ↑↓ ARE ACTIVE
USE '*' TO INITIATE COMPUTATION.  ENTER DATA TO CHANGE
```

Figure 8. Page 1 of plant data.



```
===============================================================
DATA FOR PLANT TEST          PAGE  1 OF  2
===============================================================
  BOILER SIZE                                     150_   500 MW NET
  CAPACITY FACTOR                                        70.0 %
  CHEM. ENG. PLANT COST INDEX                           270.0
  EMISSION LIMIT                                         43.0 NG/J
  PLANT ALTITUDE                                          300 M
  INTEREST RATE                                         15.00 %/YR
  COST OF ELECTRICITY                                   30.00 MIL/KWH
  CONTINGENCY AS PERCENT OF FIELD COST                   20.0 %
  ENGINEERING AS PERCENT OF FIELD COST                   20.0 %
  STEAM CYCLE EFFICIENCY                                 38.0 %

USE ← FOR CORRECTIONS
ENTER REST OF ITEM AND <ENTER> TO CHANGE
```

Figure 9. Changing a plant parameter.

points to it. You can move the arrow by pressing the <↑> or <↓> keys. Notice the message at the top of the display says

DATA FOR PLANT TEST PAGE 1 of 2

and one of the messages at the bottom of the screen says

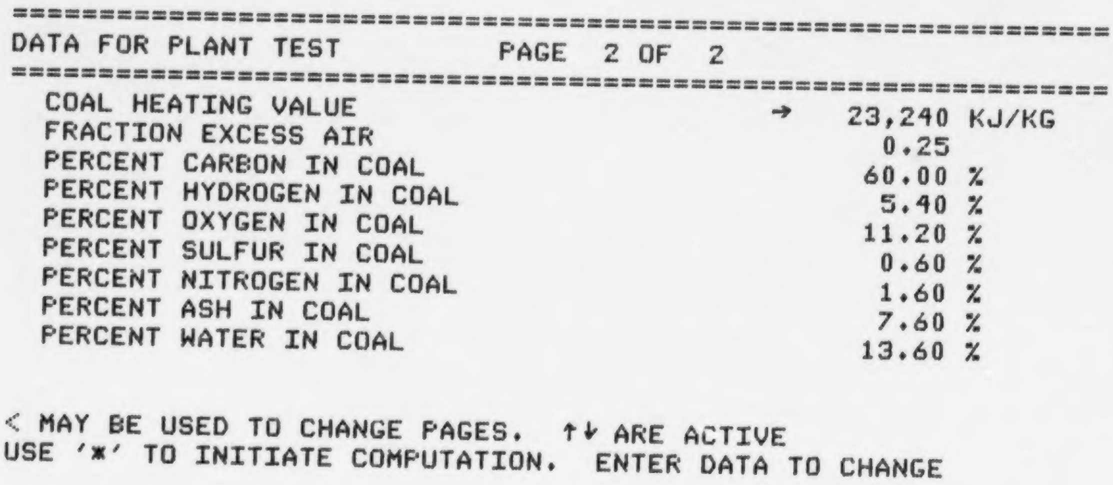
> MAY BE USED TO CHANGE PAGES.

Press the <SHIFT> and > keys simultaneously. The screen will clear again and page 2 of the plant data will be shown with the default values (see Figure 10). Again let us say that the default values are adequate with the exception of the COAL HEATING VALUE. Let us say that the coal in which we are interested has a heating value of only 20,700 kJ/kg (9,000 Btu/lb). We can change the value since the arrow is pointing at 23,240. Type

20,700<ENTER>

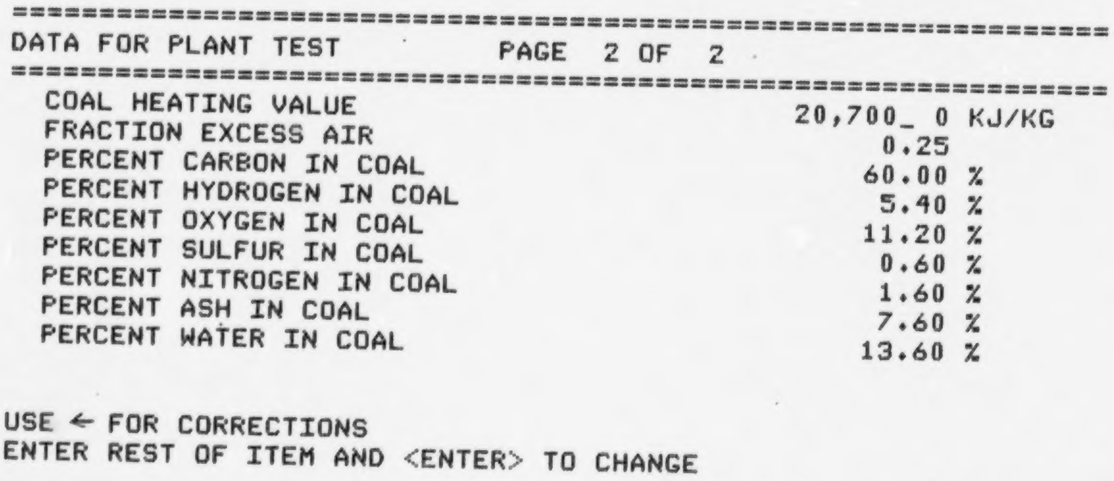
Once again the numbers will be printed on the screen to the left of the old number as you type them in (see Figure 11). Notice that you can enter commas as well as "E-Format" numbers (e.g., 2.07E4). Remember: Any number on the screen can be changed when the arrow points to it. Use the <↑> and <↓> keys to move the arrow up or down the list. If you don't change any numbers, the program will use the default values. If you do change a number, the program will use the number you have entered. If you wish to go back to page 1, then press the <SHIFT> and < keys simultaneously. The main advantage of the menu approach is that you can quickly and easily change the values of interest. If you make a mistake, you can change it again. If you get confused, try typing the <@> key. The program will know you want help and will display the instruction message again.

When you have entered all of your data and checked for errors, press the <SHIFT> and <*> keys simultaneously. The program will then assign the values you have entered (or the default values) to the proper variables and do some preliminary calculations. When it has finished these calculations, the screen will clear and you will be asked if there is a flue gas desulfurization (FGD) system associated with the particulate control device. Answer with either <Y> or <N>. This concludes the plant input part of the program. A file will now be created on the diskette to save all of the plant information so you won't



```
==============================================================
DATA FOR PLANT TEST          PAGE  2 OF  2
==============================================================
  COAL HEATING VALUE                          →   23,240 KJ/KG
  FRACTION EXCESS AIR                               0.25
  PERCENT CARBON IN COAL                           60.00 %
  PERCENT HYDROGEN IN COAL                          5.40 %
  PERCENT OXYGEN IN COAL                           11.20 %
  PERCENT SULFUR IN COAL                            0.60 %
  PERCENT NITROGEN IN COAL                          1.60 %
  PERCENT ASH IN COAL                               7.60 %
  PERCENT WATER IN COAL                            13.60 %

< MAY BE USED TO CHANGE PAGES.  ↑↓ ARE ACTIVE
USE '*' TO INITIATE COMPUTATION.  ENTER DATA TO CHANGE
```

Figure 10. Page 2 of plant data.



```
==============================================================
DATA FOR PLANT TEST          PAGE  2 OF  2
==============================================================
  COAL HEATING VALUE                          20,700_ 0 KJ/KG
  FRACTION EXCESS AIR                               0.25
  PERCENT CARBON IN COAL                           60.00 %
  PERCENT HYDROGEN IN COAL                          5.40 %
  PERCENT OXYGEN IN COAL                           11.20 %
  PERCENT SULFUR IN COAL                            0.60 %
  PERCENT NITROGEN IN COAL                          1.60 %
  PERCENT ASH IN COAL                               7.60 %
  PERCENT WATER IN COAL                            13.60 %

USE ← FOR CORRECTIONS
ENTER REST OF ITEM AND <ENTER> TO CHANGE
```

Figure 11. Entering a large number.

have to enter it all in again next time. The program will inform you that it is creating a file by printing the message

FILING PLANT DATA

as in Figure 12.

After the plant file has been created, a new message will be printed on the screen as in Figure 13. You must now select a control device for cost estimation. You may press either <1>, <2>, or <3> according to the device in which you are interested. For the purposes of this demonstration, press <1>.

Figure 14 shows the preliminary information that the program asks for in the case of an ESP. The ESP NAME is used for identification so that once this information is stored on the disk it can be recalled by its name, in this case VENDOR 1. Type in

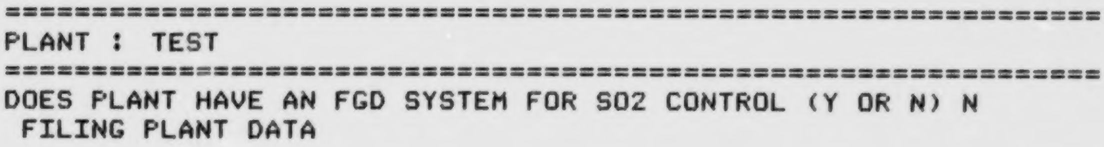
VENDOR1<ENTER>

The REMARKS are for your benefit to help identify this cost estimate. Type in any message and press <ENTER>. The ESP can be either a hotside or a coldside unit. Answer <C> (we'll do hotside later). In the event that a scrubber is used after the ESP, answer <Y>. If you do so, the program will route you to the section for venturi scrubber input later on. For now simply answer with <N>.

Page 1 of the ESP data will be displayed as shown in Figure 15. Try moving the arrow down to point at the value of 55 for the SPECIFIC COLLECTION AREA. Change this value to 65 just as you changed the values before in the plant input section. That is

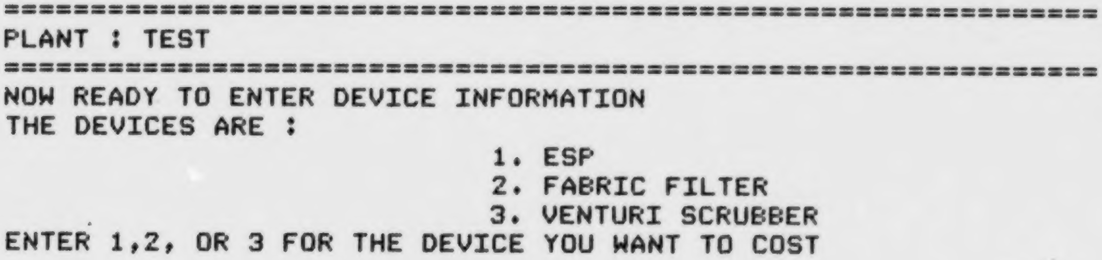
65<ENTER> .

Use the <SHIFT> and > keys simultaneously to go to page 2 of the ESP data. It should appear as in Figure 16. In general, the information on menu page 2 of the input for each control device is less important than the information on page 1. For example, the duty factors listed in Figure 16 do not enter into the calculation of the capital cost; they are only used to determine the electrical requirements for the collector system. Often these duty factors will be unknown, in which case the default values provided can be used. Any discrepancies between the assumed values and the true values will cause an imperceptible error in the predicted value of electrical requirements. Press <SHIFT> <*>.



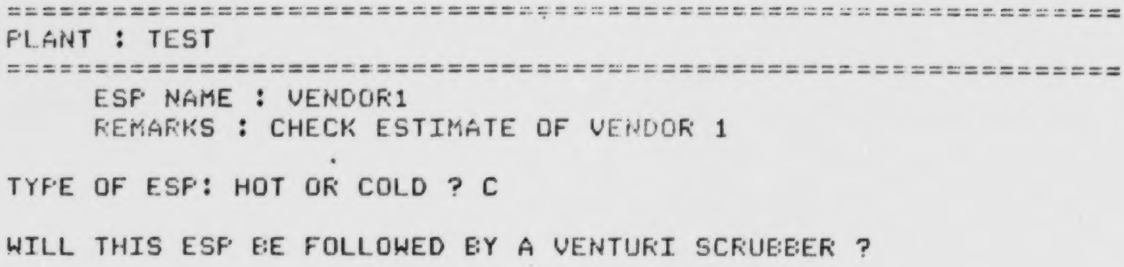
```
===============================================================
PLANT :  TEST
===============================================================
DOES PLANT HAVE AN FGD SYSTEM FOR SO2 CONTROL (Y OR N) N
 FILING PLANT DATA
```

Figure 12. The program will create a plant file.



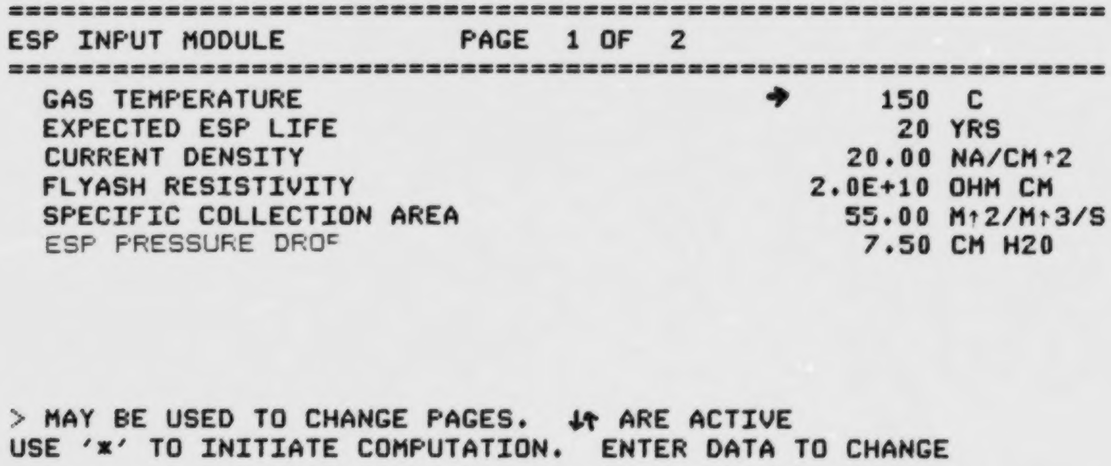
```
===============================================================
PLANT : TEST
===============================================================
NOW READY TO ENTER DEVICE INFORMATION
THE DEVICES ARE :
                            1. ESP
                            2. FABRIC FILTER
                            3. VENTURI SCRUBBER
ENTER 1,2, OR 3 FOR THE DEVICE YOU WANT TO COST
```

Figure 13. Selection of a control device.



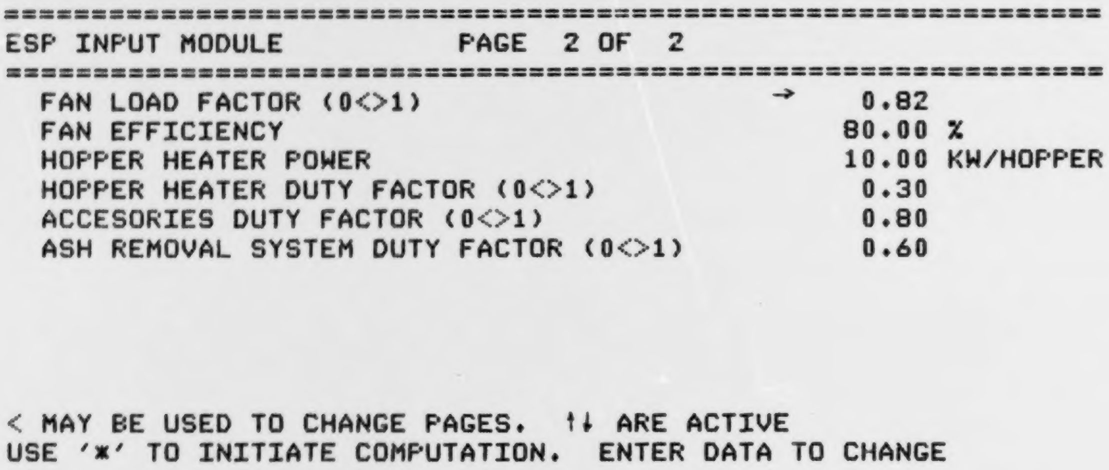
```
==================================================================
PLANT : TEST
==================================================================
     ESP NAME : VENDOR1
     REMARKS : CHECK ESTIMATE OF VENDOR 1

TYPE OF ESP: HOT OR COLD ? C

WILL THIS ESP BE FOLLOWED BY A VENTURI SCRUBBER ?
```

Figure 14. Preliminary ESP information.



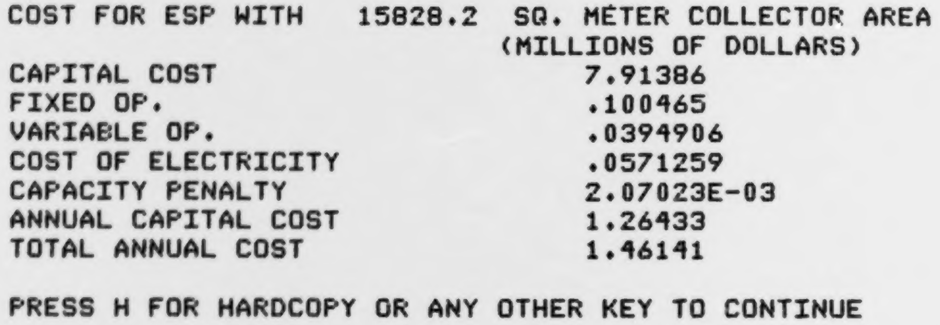
```
===============================================================
ESP INPUT MODULE          PAGE  1 OF  2
===============================================================
  GAS TEMPERATURE                                 ➔     150  C
  EXPECTED ESP LIFE                                       20 YRS
  CURRENT DENSITY                                      20.00 NA/CM↑2
  FLYASH RESISTIVITY                                 2.0E+10 OHM CM
  SPECIFIC COLLECTION AREA                             55.00 M↑2/M↑3/S
  ESP PRESSURE DROP                                     7.50 CM H2O



> MAY BE USED TO CHANGE PAGES.  ↓↑ ARE ACTIVE
USE '*' TO INITIATE COMPUTATION.  ENTER DATA TO CHANGE
```

Figure 15. Page 1 of ESP data showing default values.



```
===============================================================
ESP INPUT MODULE          PAGE  2 OF  2
===============================================================
  FAN LOAD FACTOR (0<>1)                        →     0.82
  FAN EFFICIENCY                                     80.00 %
  HOPPER HEATER POWER                                10.00 KW/HOPPER
  HOPPER HEATER DUTY FACTOR (0<>1)                    0.30
  ACCESORIES DUTY FACTOR (0<>1)                       0.80
  ASH REMOVAL SYSTEM DUTY FACTOR (0<>1)               0.60



< MAY BE USED TO CHANGE PAGES.  ↑↓ ARE ACTIVE
USE '*' TO INITIATE COMPUTATION.  ENTER DATA TO CHANGE
```

Figure 16. Page 2 of ESP data showing default values.



```
COST FOR ESP WITH   15828.2  SQ. METER COLLECTOR AREA
                            (MILLIONS OF DOLLARS)
CAPITAL COST                     7.91386
FIXED OP.                        .100465
VARIABLE OP.                     .0394906
COST OF ELECTRICITY              .0571259
CAPACITY PENALTY                 2.07023E-03
ANNUAL CAPITAL COST              1.26433
TOTAL ANNUAL COST                1.46141

PRESS H FOR HARDCOPY OR ANY OTHER KEY TO CONTINUE
```

Figure 17. Video display of program results.

The computer will print its THINKING message while it computes the capital and operating costs of this precipitator. When it has finished the calculations it will list the results on the video screen as shown in Figure 17. If you have a line printer connected to your computer, you can press <H> to get a two-page listing like the one shown in Figures 18 and 19. Page 1 of the hardcopy listing contains all of the plant data. Page 2 of the hard copy shows the ESP input values and the cost results. If you don't want a hard copy at this time, press any key besides <H>. When you do this (or after the hard copy is finished), the program will store this information in the same file with the plant data. This information can be recalled later for a complete hard-copy listing of the results.

After the data have been saved, the message shown in Figure 20 will appear on the screen. If you wish to continue, press <Y>; press <N> if you do not. Let's say we want to look at the cost of a hotside precipitator for the same plant. Answer <Y> to both questions shown in the figure. The program already has the necessary plant data so you only have to enter the device information this time. When the program asks for a device again, type <1>. Call this precipitator VENDOR 2. The program will now check to make sure that you did not already create a file for VENDOR 2. The message

CHECKING FOR EXISTING FILE

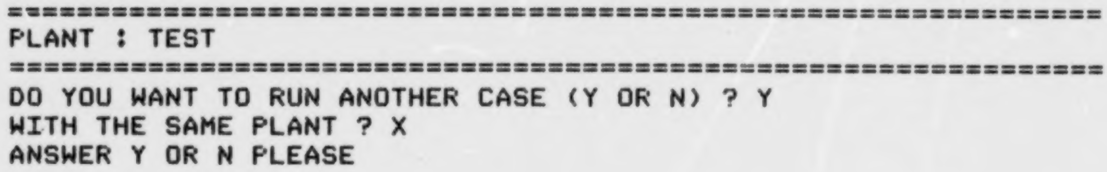
will be displayed on the screen. Since there is no record of an ESP named VENDOR 2 the program will proceed to ask you for REMARKS just as in the case of VENDOR1. Specify a <H>otside design with no scrubber. As with the cold-side ESP, change the SPECIFIC COLLECTION AREA to 65 $m^2/m^3/s$ and initiate the computations with <SHIFT><*>. Compare the results with those shown in Figure 21. Now try estimating the cost of a fabric filter using only the default values. After you're specified a name and entered your REMARKS, the first page of baghouse default values will be displayed. Pages 1 and 2 of the baghouse data are shown in Figure 22. To estimate the cost of the default case baghouse, just type <SHIFT><*>. Compare these results to those shown in Figure 23. The menu pages 1 and 2 for the venturi scrubber are shown in Figure 24. Try running the default case for the scrubber. Compare your results with the ones shown in Figure 25. Note that there are two video displays for the scrubber. The first gives the results of the estimation of capital and operating costs

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1        PAGE 1 OF 2

PLANT : TEST
DATE : 06/12/81
REMARKS : DEMONSTRATION OF COST PROGRAM
                                          PLANT DATA
==============================================================================
     BOILER SIZE                                        150 MW NET
     CAPACITY FACTOR                                   70.0 %
     CHEM. ENG. PLANT COST INDEX                      270.0
     EMISSION LIMIT                                    43.0 NG/J
     PLANT ALTITUDE                                     300 M
     INTEREST RATE                                    15.00 %/YR
     COST OF ELECTRICITY                              30.00 MIL/KWH
     CONTINGENCY AS PERCENT OF FIELD COST              20.0 %
     ENGINEERING AS PERCENT OF FIELD COST              20.0 %
     STEAM CYCLE EFFICIENCY                            38.0 %
     COAL HEATING VALUE                              20,700 KJ/KG
     FRACTION EXCESS AIR                               0.25
     PERCENT CARBON IN COAL                           60.00 %
     PERCENT HYDROGEN IN COAL                          5.40 %
     PERCENT OXYGEN IN COAL                           11.20 %
     PERCENT SULFUR IN COAL                            0.60 %
     PERCENT NITROGEN IN COAL                          1.60 %
     PERCENT ASH IN COAL                               7.60 %
     PERCENT WATER IN COAL                            13.60 %
```

Figure 18. Page 1 of the hard-copy listing showing the plant data.

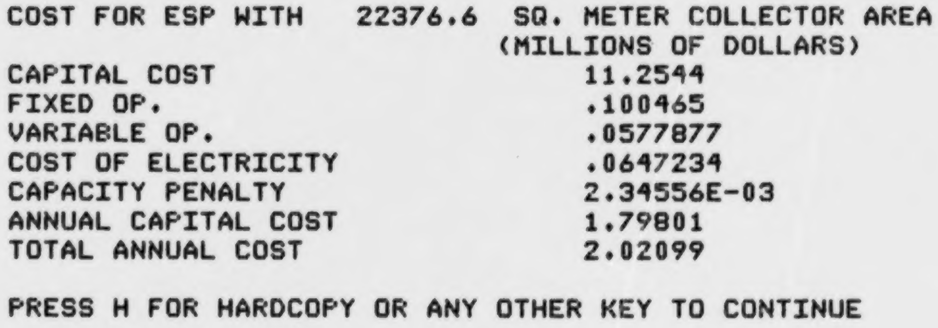
```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1        PAGE 2 OF 2
PLANT : TEST
DATE : 06/12/81

ESP NAME : VENDOR1
REMARKS : CHECK ESTIMATE OF VENDOR 1
                                              ESP DATA
==============================================================================
     GAS TEMPERATURE                                    150  C
     EXPECTED ESP LIFE                                   20 YRS
     CURRENT DENSITY                                  20.00 NA/CM[2
     FLYASH RESISTIVITY                             2.0E+10 OHM CM
     SPECIFIC COLLECTION AREA                         65.00 M[2/M[3/S
     ESP PRESSURE DROP                                 7.50 CM H20
     FAN LOAD FACTOR (0<>1)                            0.82
     FAN EFFICIENCY                                   80.00 %
     HOPPER HEATER POWER                              10.00 KW/HOPPER
     HOPPER HEATER DUTY FACTOR (0<>1)                  0.30
     ACCESORIES DUTY FACTOR (0<>1)                     0.80
     ASH REMOVAL SYSTEM DUTY FACTOR (0<>1)             0.60

                                             CONTROL SYSTEM COST

     CAPITAL COST                                             $  7.91E+06
     FIXED OPERATING COST                                     $  1.00E+05
     VARIABLE OPERATING COST                                  $  3.95E+04
     COST OF ELECTRICITY                                      $  5.71E+04
     CAPACITY PENALTY                                            2.07E-03
     ANNUAL CAPITAL COST                                      $  1.26E+06
     TOTAL ANNUAL COST                                        $  1.46E+06
```

Figure 19. Page 2 of the hard-copy listing showing ESP input data and the cost results.



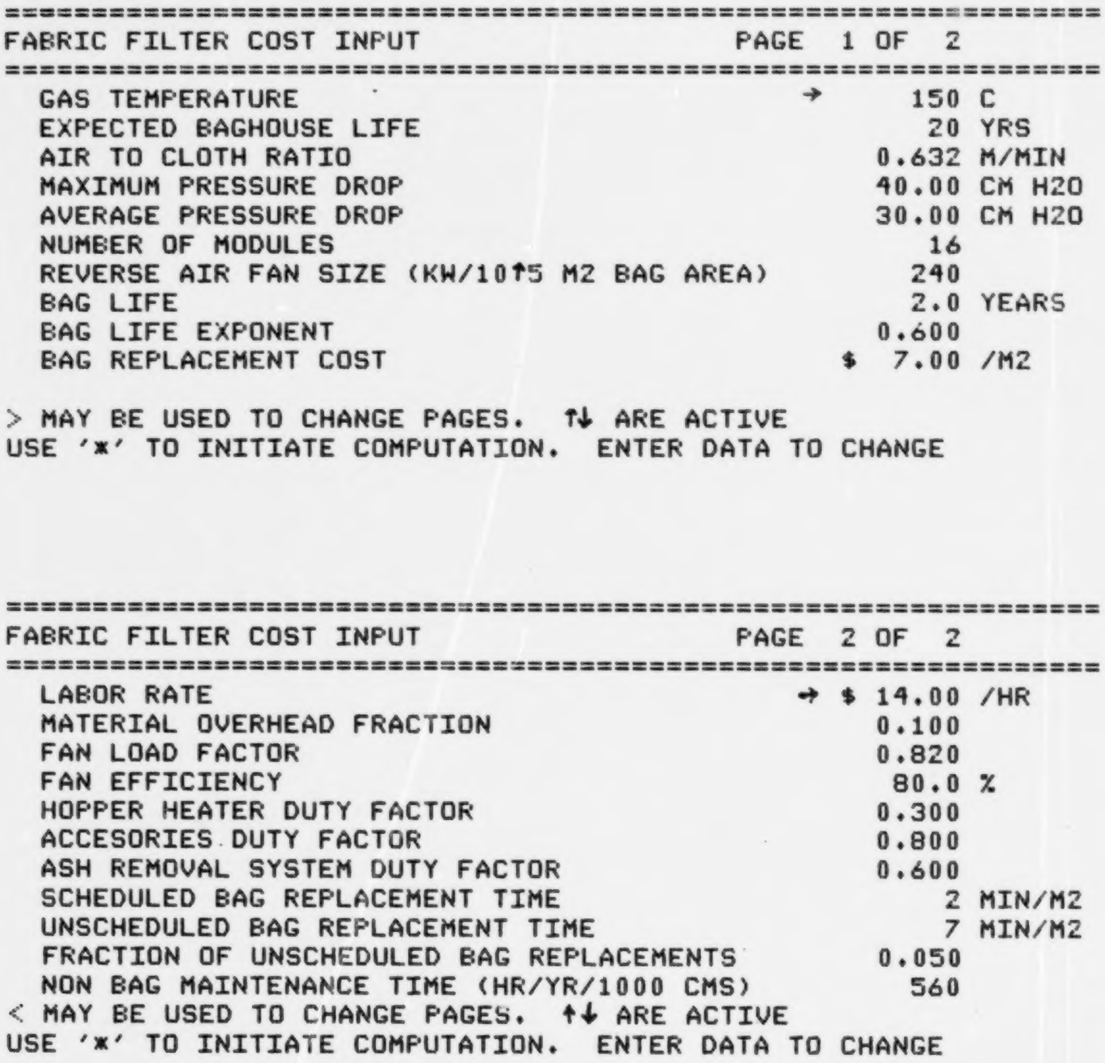
```
===============================================================
PLANT : TEST
===============================================================
DO YOU WANT TO RUN ANOTHER CASE (Y OR N) ? Y
WITH THE SAME PLANT ? X
ANSWER Y OR N PLEASE
```

Figure 20. Restarting the program.



```
COST FOR ESP WITH   22376.6  SQ. METER COLLECTOR AREA
                            (MILLIONS OF DOLLARS)
CAPITAL COST                     11.2544
FIXED OP.                        .100465
VARIABLE OP.                     .0577877
COST OF ELECTRICITY              .0647234
CAPACITY PENALTY                 2.34556E-03
ANNUAL CAPITAL COST              1.79801
TOTAL ANNUAL COST                2.02099

PRESS H FOR HARDCOPY OR ANY OTHER KEY TO CONTINUE
```

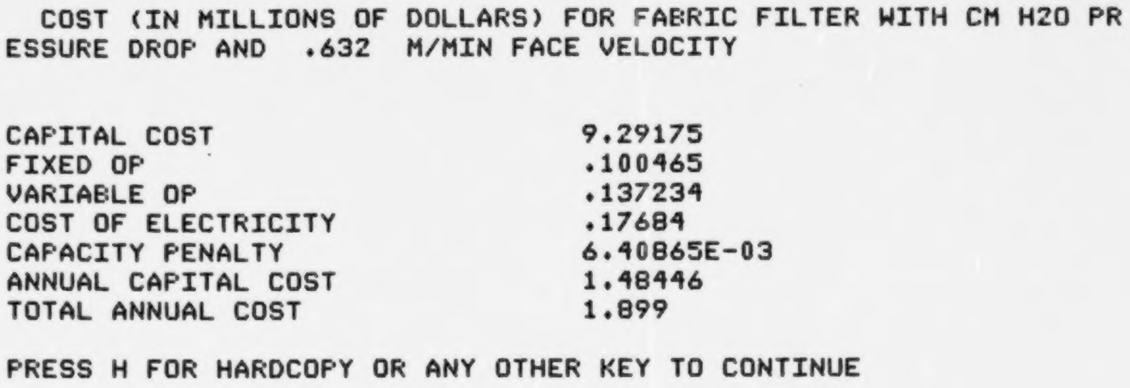
Figure 21. Hotside ESP costs.



```
===============================================================
FABRIC FILTER COST INPUT                    PAGE  1 OF  2
===============================================================
  GAS TEMPERATURE                                 →      150 C
  EXPECTED BAGHOUSE LIFE                                  20 YRS
  AIR TO CLOTH RATIO                                   0.632 M/MIN
  MAXIMUM PRESSURE DROP                                40.00 CM H2O
  AVERAGE PRESSURE DROP                                30.00 CM H2O
  NUMBER OF MODULES                                       16
  REVERSE AIR FAN SIZE (KW/10↑5 M2 BAG AREA)             240
  BAG LIFE                                               2.0 YEARS
  BAG LIFE EXPONENT                                    0.600
  BAG REPLACEMENT COST                              $   7.00 /M2

> MAY BE USED TO CHANGE PAGES.  ↑↓ ARE ACTIVE
USE '*' TO INITIATE COMPUTATION.  ENTER DATA TO CHANGE
```

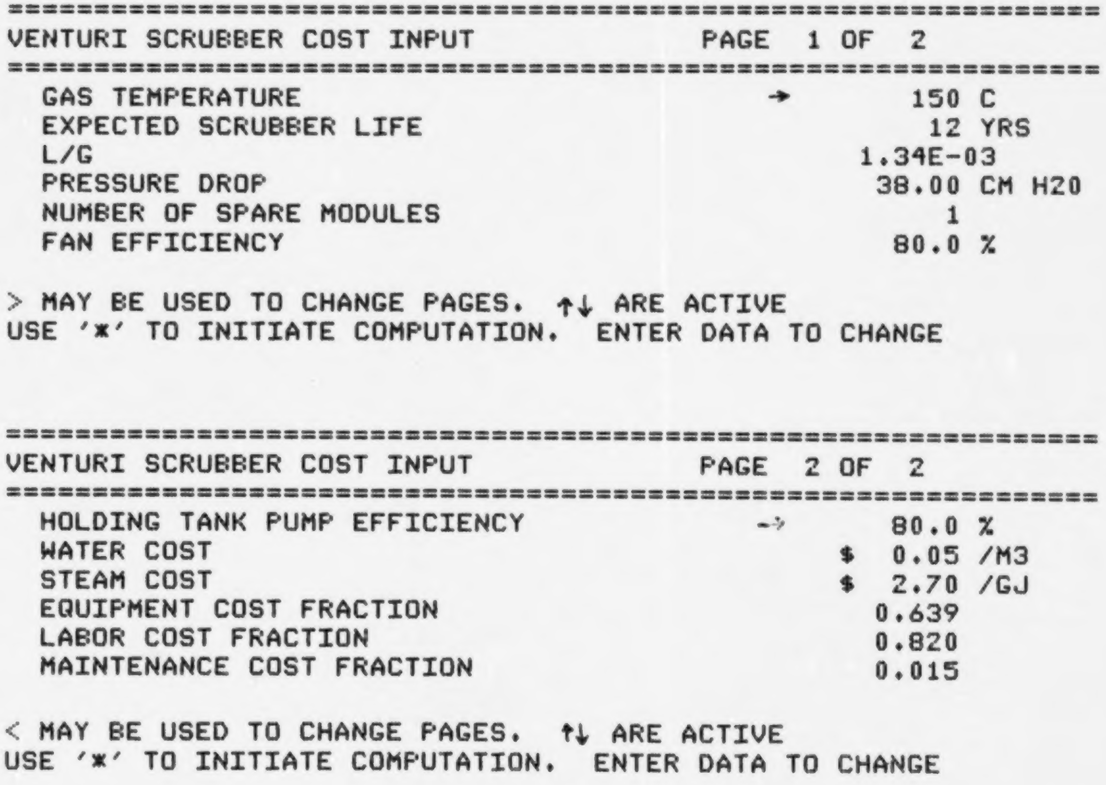
```
===============================================================
FABRIC FILTER COST INPUT                    PAGE  2 OF  2
===============================================================
  LABOR RATE                                      → $  14.00 /HR
  MATERIAL OVERHEAD FRACTION                           0.100
  FAN LOAD FACTOR                                      0.820
  FAN EFFICIENCY                                        80.0 %
  HOPPER HEATER DUTY FACTOR                            0.300
  ACCESORIES DUTY FACTOR                               0.800
  ASH REMOVAL SYSTEM DUTY FACTOR                       0.600
  SCHEDULED BAG REPLACEMENT TIME                           2 MIN/M2
  UNSCHEDULED BAG REPLACEMENT TIME                         7 MIN/M2
  FRACTION OF UNSCHEDULED BAG REPLACEMENTS             0.050
  NON BAG MAINTENANCE TIME (HR/YR/1000 CMS)              560
< MAY BE USED TO CHANGE PAGES.  ↑↓ ARE ACTIVE
USE '*' TO INITIATE COMPUTATION.  ENTER DATA TO CHANGE
```

Figure 22. Pages 1 and 2 of fabric filter data showing default values.



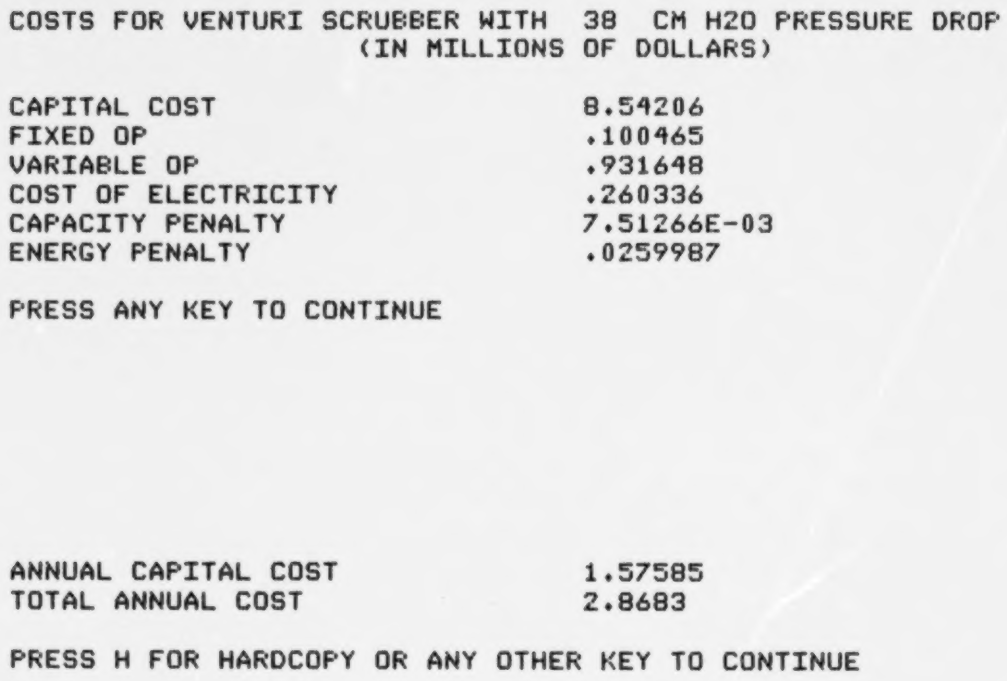
```
  COST (IN MILLIONS OF DOLLARS) FOR FABRIC FILTER WITH CM H2O PR
ESSURE DROP AND  .632  M/MIN FACE VELOCITY


CAPITAL COST                        9.29175
FIXED OP                            .100465
VARIABLE OP                         .137234
COST OF ELECTRICITY                 .17684
CAPACITY PENALTY                    6.40865E-03
ANNUAL CAPITAL COST                 1.48446
TOTAL ANNUAL COST                   1.899

PRESS H FOR HARDCOPY OR ANY OTHER KEY TO CONTINUE
```

Figure 23. Video display of the default case fabric filter costs.



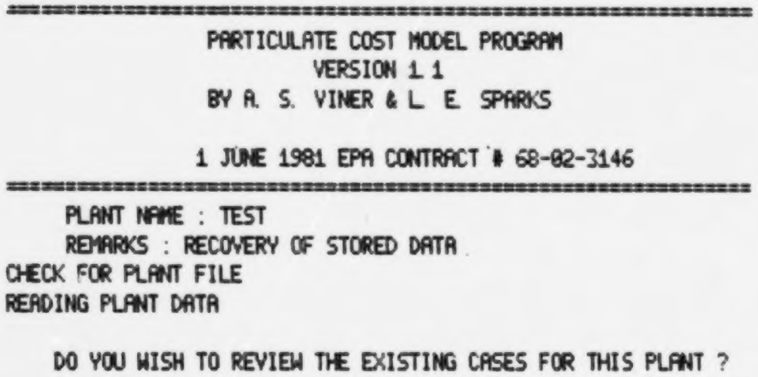
```
===============================================================
VENTURI SCRUBBER COST INPUT             PAGE  1 OF  2
===============================================================
  GAS TEMPERATURE                             →        150 C
  EXPECTED SCRUBBER LIFE                                12 YRS
  L/G                                               1.34E-03
  PRESSURE DROP                                      38.00 CM H20
  NUMBER OF SPARE MODULES                                1
  FAN EFFICIENCY                                      80.0 %

> MAY BE USED TO CHANGE PAGES.  ↑↓ ARE ACTIVE
USE '*' TO INITIATE COMPUTATION.  ENTER DATA TO CHANGE


===============================================================
VENTURI SCRUBBER COST INPUT             PAGE  2 OF  2
===============================================================
  HOLDING TANK PUMP EFFICIENCY                →       80.0 %
  WATER COST                                     $  0.05 /M3
  STEAM COST                                     $  2.70 /GJ
  EQUIPMENT COST FRACTION                           0.639
  LABOR COST FRACTION                               0.820
  MAINTENANCE COST FRACTION                         0.015

< MAY BE USED TO CHANGE PAGES.  ↑↓ ARE ACTIVE
USE '*' TO INITIATE COMPUTATION.  ENTER DATA TO CHANGE
```

Figure 24. Pages 1 and 2 of venturi scrubber data showing default values.



```
COSTS FOR VENTURI SCRUBBER WITH  38  CM H2O PRESSURE DROP
                    (IN MILLIONS OF DOLLARS)

CAPITAL COST                    8.54206
FIXED OP                        .100465
VARIABLE OP                     .931648
COST OF ELECTRICITY             .260336
CAPACITY PENALTY                7.51266E-03
ENERGY PENALTY                  .0259987

PRESS ANY KEY TO CONTINUE







ANNUAL CAPITAL COST             1.57585
TOTAL ANNUAL COST               2.8683

PRESS H FOR HARDCOPY OR ANY OTHER KEY TO CONTINUE
```

Figure 25. Costs for the default case venturi scrubber.



```
==============================================================
                PARTICULATE COST MODEL PROGRAM
                        VERSION 1.1
                BY A. S. VINER & L. E. SPARKS

            1 JUNE 1981 EPA CONTRACT # 68-02-3146
==============================================================
     PLANT NAME : TEST
     REMARKS : RECOVERY OF STORED DATA
CHECK FOR PLANT FILE
READING PLANT DATA

    DO YOU WISH TO REVIEW THE EXISTING CASES FOR THIS PLANT ?
```

Figure 26. Retrieving plant data from a file.

for the scrubber. The second display shows the total annual and annual capital costs. These costs are displayed separately to allow for the inclusion of the case of an ESP and scrubber in series.

We hope that you are now familiar with the data input and the menu format of the COST program. You should also understand the flow of the program by now. Now lets look a little more closely at the data files. The data files are set up on the assumption that a person will be interested in comparing the cost of different devices for a given plant. Information is retrieved from a data file by specifying a plant name and the name of the control device to be retrieved. Here is an example of how it works. Lets say that you have run the cases above and then ended the program. A week later you've lost the hard-copy printout and can't remember what information you entered and what the results were. Begin by starting the program just as before; enter the date and read the instructions again if you so desire. When the program asks for the plant name, enter the same name you used before:

```
PLANT NAME:  TEST<ENTER>
```

and then enter some REMARKS. After you have entered your remarks and hit <ENTER> the program will look for a file that contains data on that plant. Presumably nothing has happened to your file and the programs will find it and begin reading the data. When it does find your file it will print the message

```
READING PLANT DATA
```

as shown in Figure 26. At this time you will have the opportunity to review the data that are stored in your file. If you answer <Y> to the question shown in the figure then the program will get the first record and display the identification information on the screen as shown in Figure 27. When you press <ENTER> (or any other key), the program will display the same information for the second record. Each record represents one control device. After all of the records have been displayed, the message

```
FILE LISTING COMPLETE
DO YOU WANT A HARDCOPY OF THIS DIRECTORY?
```

will appear on the screen (see Figure 28). If you answer <Y> to the question, the program will send the record information to the line printer. If the line printer is not ready, the program will wait until you press <ENTER> and try

```
==================================================================
PLANT : TEST
==================================================================

    RECORD # :  1                    DATE : 06/12/81
    TYPE : ESP                       NAME : VENDOR1
    REMARKS : CHECK ESTIMATE OF VENDOR 1

PRESS <ENTER> WHEN READY TO CONTINUE
```

Figure 27. Displaying record information.

```
==================================================================
PLANT : TEST
==================================================================
    FILE LISTING COMPLETE
    DO YOU WANT A HARDCOPY OF THIS DIRECTORY ? Y

    PRESS <ENTER> WHEN THE LINE PRINTER IS READY

DO YOU WANT ENGLISH OR METRIC UNITS (E OR M)
```

Figure 28. Obtaining a hard copy listing of a file's content.

again. A sample listing is shown in Figure 29. After the printer has finished, the program asks for the type of units (English or metric) desired. After you answer <E> or <M>, the program will skip to the section for selecting a control device. Notice that you did not have to enter the plant data again. Once a plant file has been created, the data in that file cannot be altered. To redefine the parameters of that plant you must either start over and give it a new name or KILL (pp. 4-19 and 7-28 of the TRSDOS manual) the plant file and start over again.

After reviewing the record information for the file we decide to retrieve the cost estimate for the baghouse (record 3 in Figure 29). When the program asks you to select a control device, enter <2>. When asked the name of the baghouse type

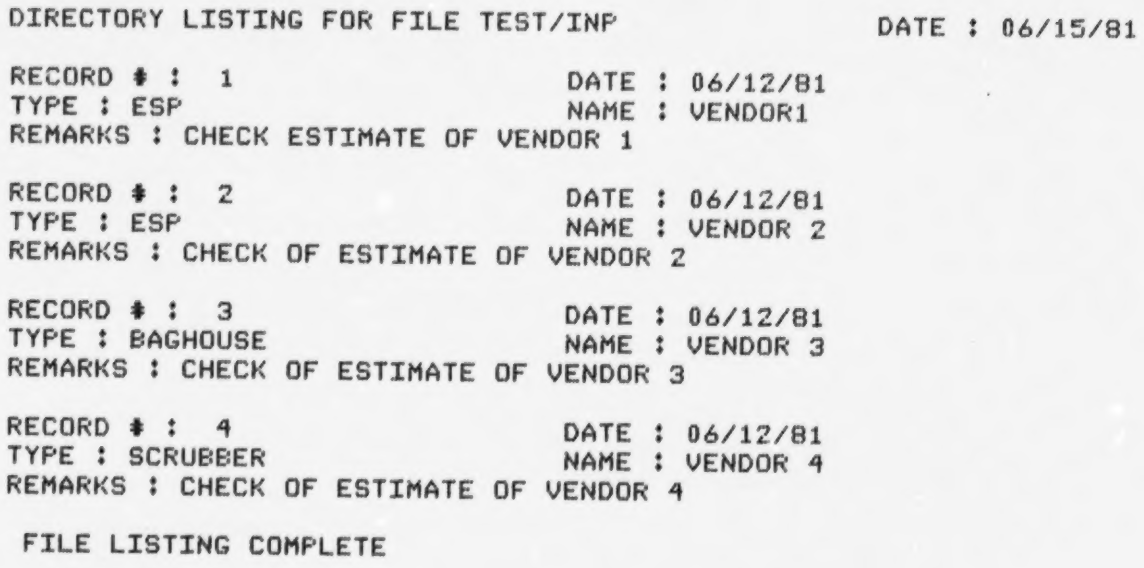
```
VENDOR 3<ENTER>
```

as shown in Figure 30. The program will search the file of plant TEST for a baghouse whose name is VENDOR 3. When the record containing information on the baghouse VENDOR 3 is found, the program will read the data from the diskette, do some quick calculations, and then print out the ANNUAL CAPITAL COST and the TOTAL ANNUAL COST for this baghouse. At this time the user can request a complete hard-copy listing of all of the plant and control device input data and the results.

5.5 DESCRIPTION OF PROGRAM OUTPUT

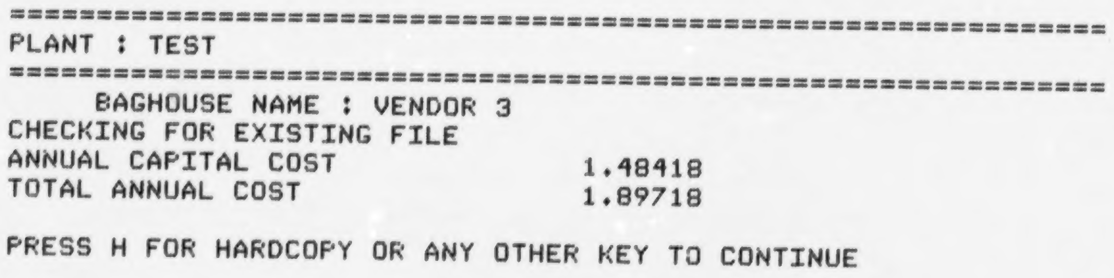
The results of the cost estimation are divided into the following categories for ease of comparison:

1. Capital cost: the complete installed cost of the collector, the ash removal system, and the ash pond plus the engineering and contingency costs.
2. Fixed operating cost: the cost of operating labor.
3. Variable operating cost: any operating material costs and the cost of labor and materials for maintenance.
4. Cost of electricity: the charge for power to run all electrical equipment associated with the collector, ash removal system, and ash pond.



```
DIRECTORY LISTING FOR FILE TEST/INP                     DATE : 06/15/81

RECORD # :  1                    DATE : 06/12/81
TYPE : ESP                       NAME : VENDOR1
REMARKS : CHECK ESTIMATE OF VENDOR 1

RECORD # :  2                    DATE : 06/12/81
TYPE : ESP                       NAME : VENDOR 2
REMARKS : CHECK OF ESTIMATE OF VENDOR 2

RECORD # :  3                    DATE : 06/12/81
TYPE : BAGHOUSE                  NAME : VENDOR 3
REMARKS : CHECK OF ESTIMATE OF VENDOR 3

RECORD # :  4                    DATE : 06/12/81
TYPE : SCRUBBER                  NAME : VENDOR 4
REMARKS : CHECK OF ESTIMATE OF VENDOR 4

 FILE LISTING COMPLETE
```

Figure 29. Hard copy of file directory.



```
================================================================
PLANT : TEST
================================================================
     BAGHOUSE NAME : VENDOR 3
CHECKING FOR EXISTING FILE
ANNUAL CAPITAL COST                1.48418
TOTAL ANNUAL COST                  1.89718

PRESS H FOR HARDCOPY OR ANY OTHER KEY TO CONTINUE
```

Figure 30. Retrieving device data.

5. Annual capital cost: the cost of the particulate control system and the interest on money borrowed averaged over the lifetime of the control device.

6. Total annual cost: the sum of the annual capital cost, the operating costs, and the electricity costs; represents the annual cost of owning and operating the particulate control system in the year it was built.

7. Capacity penalty: the percentage of gross generating capacity that must be diverted from distribution to meet the needs of the control device and associated equipment.

SECTION 6

OTHER PROGRAMMING CONSIDERATIONS

This section addresses the hodge-podge of questions associated with the COST program. Although it is not possible to anticipate every question nor consider every scenario, the intent here is to point the reader in the right direction and give some helpful hints on how and where to change the program to achieve the desired results.

If you are a beginner, it is strongly suggested that you practice writing and editing simple BASIC programs before attempting any changes in the COST program. The DISK BASIC commands LOAD, LIST, EDIT, and SAVE must be learned first. Pay particular attention to the BASIC method of handling subroutines.

Section 6.1 indicates changes necessary to adapt the program for emission sources other than coal. The calculation of the flue gas flow rate is also discussed. Section 6.2 describes the structure of the data files used for the plant and device data. Section 6.3 considers the possibility of estimating the costs of novel control devices even though there is no cost data base for them. Section 6.4 offers suggestions for implementing this program on a system other than the TRS-80® Model I or Model III microcomputer.

6.1 DISCUSSION OF FLOW RATE AND EMISSIONS CALCULATIONS

The COST program uses the information on the coal burned by the plant to calculate the amount of combustion air required and the amount of emissions leaving the boiler. The volume of theoretical air needed to burn coal can be determined from the equation:

$$q = 1710 \times (C/12 + H_2/4 - O_2/32 + S/32) \qquad (6.1)$$

where

q = cubic feet of air per pound of fuel and

C, H_2, O_2, and S = the fractions of these elements in the fuel as determined by the ultimate analysis.

The constant 1710 applies for gas at 0° C (32° F) and 1 atm. This value is corrected to the actual gas temperature, as supplied by you. It is also corrected to the actual pressure at the inlet of the control device using the device pressure drop and the altitude of the plant. To calculate the absolute flow rate from the value q as determined above, the coal firing rate is calculated by:

$$\text{firing rate} = \frac{\text{cf} \times \text{boiler size}}{\text{efficiency} \times \text{coal heat value}} \tag{6.2}$$

where the firing rate is calculated in units of pounds of coal per second. The constant cf is a units conversion factor and the other parameters in the equation are input required from the user. The product of the firing rate and the combustion air rate (q) gives the flow rate of theoretical air. A correction is also included to account for the excess combustion air that is usually required.

The amount of fly ash emissions leaving the boiler is determined from the equation:

$$\text{boiler emissions} = 0.8 \times \text{cf} \times \frac{\text{coal ash fraction}}{\text{coal heat value}} \tag{6.3}$$

where it is assumed that 80 percent of the ash in the coal leaves the boiler with the flue gas. The units conversion factor (cf) in this equation is different from the one in the previous equation.

Most of the process calculations listed above are shown in a subroutine entitled Variable Initialization, near line 1500 of the program listing in Appendix C. The gas temperature and pressure information is part of the control device input, so these corrections to the gas flow rate are made in different sections of the program. For ESPs, these corrections are shown in (or near) line 930. Corrections for scrubbers are shown in line 1150 and for baghouses in line 1480.

One of the easiest adjustments to make to the program is to bypass the calculation of the gas flow rate and/or boiler emissions. To bypass the calculation of boiler emissions and insert your own value, locate the line near 1570 that contains the statement:

```
PB=0.8×X(18)×1E7/X(11)
```

and amend it in the following way:

```
PB=0.8×X(18)×1E7/X(11)  :  CLS  :  INPUT "BOILER EMISSIONS =";PB
```

With this change, the program will stop and wait for you to input the boiler emissions (units: ng/J) immediately after you initiate the computations on the plant data (i.e., after you press <SHIFT> <*>).

To insert your own flow rate you must first determine the control device in which you are interested. For purposes of demonstration, let us assume a fabric filter. In the fabric filter input subroutine at line 1480 there is the statement:

```
GC=CB×(GT+273) . . . .
```

Amend this line at the end to include:

```
GC=GB×(GT+273) . . . .   : CLS : INPUT "GAS FLOWRATE =";GC
```

In this case the program will stop immediately after computations are initiated on the baghouse data. The program will wait for you to enter the actual gas flow rate in units of cubic meters per second. The same adjustment can be made for an ESP in line 930 or a scrubber in line 1150.

The comments above assume that you are interested in computing the cost of particulate control for a coal-fired boiler but that you have a specific flow rate or boiler emission in mind for which the calculations of the program are insufficient. On the other hand, you may also be interested in particulate control for a furnace or kiln, in which case the above equations will be unsuitable for your purposes. It is possible to accommodate your needs; however, the number of programming changes will be significantly greater. Study the program first and understand how it works. It may be desirable to incorporate the boiler emissions into one of the plant input menus and the gas flow rate into one of the menu pages of device input. Besides these changes, it will be necessary to change the calculation of ash quantity in lines 4020, 4440, and 4720 and delete the calculation of the capacity penalty in lines 4200, 4320, 4570, and 4780. The calculation of the scrubber energy penalty in line 4580 should also be deleted.

Any changes to any of the menu pages requires accompanying changes in the string and default value initialization subroutines beginning at line 2790. The parameter initialization statements following each input routine will also have to be changed along with the structure of the data files, including all GET, PUT, LSET, and FIELD statements. Remember, do not make these changes to your original COST program diskette--use a copy instead. Good luck.

6.2 COST PROGRAM DATA FILES

The COST program uses DISK BASIC random access files to store data on diskettes. The random access files have the advantages of being fast and compact; however, they are difficult to change. The mechanics of this type of file are explained in the TRSDOS reference manual. The FIELD statements used in the program begin at line 5450 for the plant data and cost results. The remaining FIELD statements are contained in subsequent subroutines. Some parameters are scaled for easy storage as integer values because integers take up less space in random access files. (For example, a value that typically ranges from 0.01 to 1.00 may be multiplied by 100 to make it an integer value from 1 to 100.) Also, whatever changes are made in the output subroutines require corresponding changes in the input subroutines. The structure of a file record containing data for a plant and an ESP is shown in Figure 31. The variable names shown in the figure can be identified with the aid of the cross-reference listing in Appendix D.

6.3 EXTENSION OF THE PROGRAM TO NOVEL DEVICES

The program can be extended to a small degree to cover improvements in the design and/or technology of established techniques. For example, the program can be extended to predict the cost of an ESP with a pulse power supply by adjusting the base case cost to reflect the cost of the new power supply. Specifically: the base case cost of the coldside ESP account is currently \$4.72 million. If the new pulse power supplies can be expected to add 10 percent to the cost of the collector, then the base case cost in the program would be replaced with a value of \$5.19 million. One can expect that the more novel a technology is, the less reliable this approach will be.

When a new technology is introduced, it is with the intention of reducing the capital cost or the operating cost or both. Consequently, anyone interested in changing the program for some new technology should be aware of and make adjustments for any changes in the operating cost.

6.4 MISCELLANEOUS SPECULATION

The program was written for a TRS-80® Model I Level II microcomputer with at least one floppy disk drive and 48K of memory. In adapting this program to a non-Radio Shack computer, one should be aware of differences in BASIC dia-

<table>
<tr><th></th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th><th>9</th><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th></tr>
<tr><td>0</td><td colspan="2">SZ</td><td colspan="2">CF</td><td colspan="2">CE</td><td colspan="4">PL</td><td colspan="2">PA</td><td colspan="4">IR</td></tr>
<tr><td>1</td><td colspan="2">CK</td><td colspan="2">MC</td><td colspan="2">EF</td><td colspan="2">TE</td><td colspan="2">HV</td><td colspan="2">EA</td><td colspan="2">C1</td><td colspan="2">H1</td></tr>
<tr><td>2</td><td colspan="2">02</td><td colspan="2">S2</td><td colspan="2">N2</td><td colspan="2">FA</td><td colspan="2">W</td><td colspan="2">FI$</td><td colspan="4">PLANT</td></tr>
<tr><td>3</td><td colspan="16">REMARKS</td></tr>
<tr><td>4</td><td colspan="16">PLANT REMARKS</td></tr>
<tr><td>5</td><td colspan="16"></td></tr>
<tr><td>6</td><td colspan="16">PLANT REMARKS</td></tr>
<tr><td>7</td><td></td><td colspan="8">DT$</td><td colspan="7">Z$</td></tr>
<tr><td>8</td><td></td><td colspan="2">A</td><td colspan="8">ES$</td><td colspan="2">GT</td><td colspan="2">LP</td><td>CD</td></tr>
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<tr><td>B</td><td colspan="16">Empty</td></tr>
<tr><td>C</td><td colspan="15">Empty</td><td></td></tr>
<tr><td>D</td><td colspan="16">ESP REMARKS</td></tr>
<tr><td>E</td><td colspan="16">ESP REMARKS</td></tr>
<tr><td>F</td><td colspan="7"></td><td colspan="2">CC$</td><td colspan="2">FO$</td><td colspan="2">VO$</td><td colspan="2">EC$</td><td></td></tr>
</table>

Figure 31. ESP data file structure.

lects and data file handling. For example, the bulk of the program, as it is, will operate on an Apple® computer. It is not known at this time what problems might arise in managing the data files.

The COST program is compatible with the Microsoft BASIC compiler; however, it is simply too long to link and run. The fact that is is compatible with the compiler indicates that the COST program should also be compatible with Microsoft's BASIC 5.0 for CP/M-based systems; however, we have no way of verifying this.

SECTION 7

REFERENCES

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APPENDIX A
GLOSSARY

APPENDIX A

A.1 GLOSSARY

This glossary is divided into several sections for ease of reference. Section A.2 contains definitions of all of the terms used in the plant input menu pages. Sections A.3, A.4, and A.5 contain definitions of terms used in the ESP, baghouse, and scrubber menu pages, respectively. The fifth section lists definitions of terms used in the program output, and the final section lists definitions of important terms not covered in any of the preceding sections.

A.2 PLANT INPUT PARAMETERS

Boiler size: The net generating capacity of the pulverized coal-fired boiler for which the particulate control device is intended. Units: megawatts (MW).

Capacity factor: A reflection of the boiler's load and total operating time. Specifically, the product of the average capacity at which the unit is operating times the fraction of the year during which the plant operates based on 8,760 hours per year. Units: percent (%).

Chemical Engineering Plant Cost Index: A multiplier used to update costs from past to present, published twice monthly in Chemical Engineering magazine. Units: none.

Coal heating value: The unit heat content of the pulverized coal burned in the boiler. Units: kilojoules per kilogram (kJ/kg) or British thermal units per pound (Btu/lb).

Contingency as percentage of field cost: Errors and unknowns in estimation are accounted for with this multiplier. All of the capital costs are estimated and this percentage is added to take care of contingencies. Units: percent (%).

Cost of electricity: The cost of electricity to run all equipment in the system such as T-R sets, reverse-air fans, hopper heaters, etc. Units: mills per kilowatt-hour (mils/kWh).

Emission limit: The mass of emissions permitted to leave the stack per unit of generating capacity. Units: nanograms per Joule (ng/J) or pounds per million Btu (lb/MBtu).

Engineering as percentage of field cost: The cost of engineering and fee, which includes preparation of specifications, interface engineering, quality assurance, etc., is estimated as a fraction of the field cost. Units: percent (%).

Fraction excess air: The fraction of air fed to the boiler in excess of stoichiometric requirements for complete combustion. Units: none.

Interest rate: The current rate being charged for money. Units: percent (%).

Percent ash in coal: The percent of ash in the coal as determined by ultimate analysis.

Percent carbon in coal: The percent of carbon in the coal as determined by ultimate analysis.

Percent hydrogen in coal: The percent of hydrogen in the coal as determined by ultimate analysis.

Percent nitrogen in coal: The percent of nitrogen in the coal as determined by ultimate analysis.

Percent oxygen in coal: The percent of oxygen in the coal as determined by ultimate analysis.

Percent sulfur in coal: The percent of sulfur in the coal as determined by ultimate analysis.

Percent water in coal: The percent of water in the coal as determined by ultimate analysis.

Plant altitude: The elevation above sea level at the boiler site. Units: meters (m) or feet (ft).

Steam cycle efficiency: The thermodynamic efficiency of the energy conversion process, i.e., the efficiency of converting the coal heat value into electrical energy. Units: percent (%).

A.3 ESP INPUT PARAMETERS

Accessories duty factor: The fraction of time that the precipitator accessories are operating while the boiler is operating. Units: none.

Ash removal system duty factor: The fraction of time that the ash removal system is operating while the boiler is operating. Units: none.

Current density: The current density at which the precipitator is operated. Units: nanoamps per square centimeter (nA/cm^2).

ESP pressure drop: The drop in pressure from the inlet to the outlet of the ESP. Units: centimeters water (cm H_2O) or inches water (in. H_2O).

Expected ESP life: The number of years over which the cost of the ESP plus interest will be averaged. Units: years (yr).

Fan efficiency: The product of the ID fan efficiency and the fan motor efficiency. Units: percent (%).

Fan load factor: The ratio of the average load on the ID fan to the maximum load on the fan. Units: none.

Fly ash resistivity: The electrical resistivity of the fly ash. This term is required for recordkeeping purposes only; the resistivity is not used to determine the current density. Units: ohm-centimers (Ω-cm).

Gas temperature: The temperature of the flue gas entering the ESP. Units: degrees Celsius or Fahrenheit (°C or °F).

Hopper heater duty factor: The fraction of time that the hopper heaters operate while the boiler is operating. Units: none.

Hopper heater power: The power requirement of the ash hopper heaters. Units: kilowatts per hopper (kw/hopper).

Specific collection area (SCA): The amount of plate area required to clean a given rate of gas flow. Units: square meters per actual cubic meters per second (m^2/act m^3/s) or square feet per thousand actual cubic feet per minute (ft^2/kacfm).

A.4 FABRIC FILTER INPUT PARAMETERS

Accessories duty factor: The fraction of time that the baghouse accessories are operating while the boiler is operating. Units: none.

Air-to-cloth ratio: The gas flow rate per unit area of cloth. Units: meters per minute (m/min) or feet per minute (ft/min).

Ash removal system duty factor: The fraction of time that the ash removal system is operating while the boiler is operating. Units: none.

Average pressure drop: The average pressure drop across the baghouse. Units: centimeters water (cm H_2O) or inches water (in. H_2O).

Bag life constant: The bag life expected when the face velocity is 0.61 m/min (2.0 ft/min). Units: years (yr).

Bag life exponent: The exponent b used in the empirical equation:

$$\text{bag life} = \frac{\text{bag life constant}}{(\text{face velocity}/0.61)^b}$$

Units: none.

Bag replacement cost: The unit cost of a fabric filter bag. Units: dollars per square meter ($\$/m^2$) or dollars per square foot ($\$/ft^2$).

Expected baghouse life: The number of years over which the cost of the fabric filter plus interest will be averaged. Units: years (yr).

Fan efficiency: The product of the ID fan efficiency and the fan motor efficiency. Units: percent (%).

Fan load factor: The ratio of the average load on the ID fan to the maximum load on the fan. Units: none.

Fraction of unscheduled bag replacements: The fraction of bags in the baghouse that will require unscheduled replacement. Units: none.

Gas temperature: The temperature of the flue gas entering the baghouse. Units: degrees Celsius or Fahrenheit (°C or °F).

Hopper heater duty factor: The fraction of time that the hopper heaters operate while the boiler is operating. Units: none.

Labor rate: The cost of labor for maintenance and bag replacement including overhead. Units: dollars per hour ($/hr).

Material overhead fraction: A multiplier applied to bag cost to account for overhead.

Maximum pressure drop: The pressure drop across the baghouse when the maximum number of compartments are down for cleaning? Units: centimeters water (cm H_2O) or inches water (in. H_2O).

Nonbag maintenance time: The amount of time in a year spent on maintenance for items other than bag replacement. Units: hours per year per thousand cubic meters per second of gas flow (h/yr/1,000 cm/s).

Number of modules: The number of independent compartments in the baghouse. Units: none.

Reverse air fan size: The size of the fan used for reverse air cleaning. Units: kilowatts per 100,000-square-meter bag area (kW/100,000-m^2 bag area).

Scheduled bag replacement time: The time required for bag replacement during a scheduled outage. Units: minutes per square meter (min/m^2).

Unscheduled bag replacement time: The time required for bag replacement during an unscheduled outage. Units: minutes per square meter (min/m^2).

A.5 VENTURI SCRUBBER INPUT PARAMETERS

Equipment cost fraction: A multiplier applied to the cost of equipment to determine the cost of installation materials (e.g., steel, concrete, instrumentation, etc.). Units: none.

Expected scrubber life: The number of years over which the cost of the scrubber plus interest will be averaged. Units: years (yr).

Fan efficiency: The product of the efficiencies of the ID fan and its motor. Units: percent (%).

Gas temperature: The temperature of the flue gas as it leaves the air preheater. Units: degrees Celsius or Fahrenheit (°C or °F).

Holding tank pump efficiency: The product of the efficiencies of the holding tank circulation pump and motor. Units: percent (%).

Labor cost fraction: A multiplier applied to the cost of equipment to determine the cost of installation labor. Units: none.

L/G (liquid-to-gas ratio): The ratio of the volume of water used to the volume of gas entering the venturi at 51.7° C (125° F) and saturated. Units: none.

Maintenance cost fraction: A multiplier applied to the cost of equipment to determine the annual cost of maintenance labor and materials. Units: none.

Number of spare modules: The number of venturi modules kept on hand to ensure system availability. Units: none.

Pressure drop: The gas pressure drop across the venturi throat. Units: centimeters water (cm H_2O) or inches water (in. H_2O).

Steam cost: The unit cost of steam for reheat. Units: dollars per gigajoule ($/GJ).

Water cost: The unit cost of water in current dollars. Units: dollars per cubic meter ($/$m^3$) or dollars per cubic foot ($/$ft^3$).

A.6 OUTPUT PARAMETERS

The cost estimations produced by the program are in current dollars as represented by the CE Plant Cost Index supplied by the user. The operating costs are calculated on the basis of the capacity factor entered by the user.

Annual capital cost: A constant annual payment spread over the lifetime of the control system accounting for the capital cost of equipment and the time value of money borrowed.

Capacity penalty: The percentage of gross generating capacity used to run the particulate control system.

Capital cost: The sum of all costs incurred by engineering, purchasing, shipping, and installing a complete air pollution control system. This includes all contingencies and indirect costs.

Cost of electricity: The cost of electricity to run all equipment in the system such as T-R sets, reverse air fans, ID fans, pumps, etc.

Fixed operating cost: The annual cost of operating labor required for the collector and associated ash removal system. It is a "fixed" charge because these requirements do not change with rate of output.

Total annual cost: The annual cost of owning and operating the control system. It is the sum of the annual capital cost, the fixed operating cost, the variable operating cost, and the cost of electricity.

Total turnkey cost: The sum of all direct and indirect costs including collector system, support steel, ductwork, insulation, installation labor and materials (e.g., concrete foundation), engineering, contingency, taxes, overhead, and administrative charges.

Variable operating cost: The annual cost of maintenance labor and materials for the entire control system including collector, ash removal system, and ash pond.

A.7 GENERAL TERMS

Air pollution control system: A catch-all phrase intended to include the collector, ash removal system, and ash pond. Synonyms: particulate control system; control system.

Control device: The ESP, baghouse, or scrubber currently under discussion.

Indirect costs: The following items are included in indirect costs: land; contractor's fees and expenses (i.e., field labor; field office; personnel; temporary roadways, piping, electrical and sanitary facilities; safety; rental equipment; permits; licenses; taxes; insurance; overhead; legal expenses; and startup); engineering costs (i.e., design and profit engineering; bid analysis; cost analysis; accounting; reports; consultant fees; purchasing; inspection; safety; and field engineering); freight; taxes (sales, franchise, property, and excise); insurance (liability for equipment shipped and onsite; fire; personal injury; death; and damage to property); and shakedown costs.

APPENDIX B

COST COMPARISON DETAILS

APPENDIX B

COST COMPARISON DETAILS

The tables in this appendix show the breakdown of the costs presented in Tables 2 through 6 and Figures 1 through 3 of this report. The data were obtained from the reports cited in Table 1.

Also presented in this appendix are the printouts from the computer runs showing the input and the results of the cost predictions.

TABLE B-1. COSTS FOR GEORGE NEAL #3 PLANT
(Dollars × 10^3)

Collector and supports	
Structural	1,100
ESP	7,300
Labor (80% of reported value for total labor)	2,820
	11,220
Ducting and supports	
Ducts	1,400
Labor (20% of reported value for total labor)	700
	2,100
Ash removal	
Structural	40
Process equipment	1,470
Piping	150
	1,660
Insulation	
ESP and associated	1,180
Ash removal	30
	1,210
ESP miscellaneous	
Earthwork	261
Concrete	197
ESP piping	77
ESP electrical	823
Painting	14
	1,372
Ash handling miscellaneous	
Earthwork	40
Concrete	38
Electrical	56
Painting	2
	136
Indirect field charges	1,700
	1,700
Total miscellaneous	3,210

TABLE B-2. COSTS FOR NAVAJO PLANT
(Dollars × 10^3)

Collector & supports	
#3 ESP	4,880
#3 ESP labor & subcontracts	3,080
(80% of reported value for total labor)	
Accessory electrical equipment	7,640
Instrumentation	750
	16,350
Ducting and supports	
#3 ESP ductwork	3,300
Ductwork labor	770
(20% of reported value for total labor)	4,070
Ash removal system	
Ash collection and storage system	4,280
Ash collection installation	3,580
Ash handling piping	480
Machinery	580
	8,920
Insulation	
Equipment insulation	2,160
Miscellaneous	
Other materials	230
Miscellaneous foundations	720
Major aux. building foundations	4
Earthwork	54
Architectural features	840
	1,850
ID fan	
Incremental costs of ESP	455
to ID fans	455
Contingency	
Changes in materials	284
Accelerated delivery of materials	849
	1,133

TABLE B-3. PLANT A COST SUMMARY
(Dollars × 10^3)

	Reported	Predicted
Total field cost + contingency	27,200	29,800
Engineering	900	5,100
	36,200	34,900

TABLE B-4. COSTS FOR NUCLA PLANT
(Dollars × 10^3)

Collector and supports	Field cost
Structural-stairways, handrails	48
Baghouse	631
Labor (80% of reported value for total labor)	278
	957
Ducting and supports	
Process equipment	
Ductwork	113
Labor (20% of reported value for total labor)	69
	182
Ash removal system	
Equipment	
--controls, valves	130
--blowers	37
Pneumatic conveyor lines	32
	199
Insulation	130
	130
Miscellaneous	
Baghouse equipment	
Earthwork	39
Concrete foundation	75
Piping-drainage and air	56
Electrical	200
Painting	50
Instrumentation	50
	470
Flyash system	
Earthwork	1
Concrete-foundations	10
Electrical	20
Painting	5
Instruments	10
	46
Indirect owner cost	
Administration	4
Engineering and supervision	31
All risk insurance	19
Travel	22
	76
Total miscellaneous	592

TABLE B-5. COSTS FOR KRAMER PLANT
(1977 Dollars × 10^3)

Collector and supports	Material		Labor
Structural	927		249
Piping	167		280
Mechanical	20		11
Baghouse modules	3,573		174
Electrical	522		*
Instrumentation	104		*
Fire protection system	1		1
Heating and ventilation	28		12
Buildings	34		34
	5,374		761
		6,135	
Ducting and suports	Material		Labor
Ductwork	574		150
		724	
Ash removal system	Material		Labor
Structural	49		40
Piping	83		†
Mechanical	16		48
Electrical	45		*
Instrumentation	16		*
Heating and ventilation	16		4
Buildings	9		4
	234		96
		33	
Insulation	Material		Labor
Baghouse	314		526
Ash removal system	17		17
	331		543
		874	

*Labor for electrical, instrumentation, and mechanical requirements is included in miscellaneous.

†Not reported.

TABLE B-5. (continued)

	Material		Labor
Miscellaneous			
Baghouse equipment			
Earthwork	181		82
Concrete	255		120
Electrical	*		480
Instrumentation	*		163
Painting	16		51
Booster fans	199		3
Flyash system			
Earthwork	24		12
Concrete	47		33
Electrical	†		55
Instrumentation	†		17
Painting	2		6
			1,022
Indirect owner costs			
Administration	5		
Engineering and supervision	215		
Insurance	21		
Travel	18		
Administrative overhead	130		
Office overhead	21		
Miscellaneous	24		
Total miscellaneous	1,158		
		2,180	
Contingency		949	
Interest during construction			
Engineering		1,560	

*Material for electrical and instrumentation is included in collector and supports.

†Material for electrical and instrumentation is included in ash removal system.

TABLE B-6. COSTS FOR SUNBURY PLANT
(Dollars × 10^3)

Collector and supports, ducting and supports, insulation			
Western precipitation contract	Material		Labor
Four baghouses	1,267		1,020
Vacuum cleaning system	30		40
Platforms, ladders, etc.	95		20
	1,392		1,080
Accessory electric equipment			
Conduit	4		*
Power cable	8		*
Control cable	24		*
	1,428		1,080
		2,448	
Miscellaneous	Material		Labor
Land and land rights	2		0
	2		0
Structures and improvements			
Foundation--baghouse	38		46
Clearing site			104
Grading	2		3
Pump house	91		89
	131		242
Accessory electrical equipment			
Conduit	*		11
Power cable	*		11
Control cable	*		14
			36
Miscellaneous	0		0
	0		0
Overhead			
Cost analysis and inspection	65		
Temporary construction power	6		
Construction supervision	10		
Removal cost	23		
	104		
Total miscellaneous		515	

(continued)

TABLE B-6. (continued)

Ash removal system	Material		Labor
Ash removal system--bag filter	244		173
Ash slurry systems	244		145
Raw water pumps	54		32
Booster pumps	45		35
Piping for extended mechanical hopper	1		4
Air piping, valves and fittings	7		10
Platforms and walkways	21		41
	616		440
		1,056	
Engineering			
Western precipitation contract			
Baghouse	493		
Hopper enclosures	70		
Overhead			
Engineering and supervision-indirect	109		
Contract engineering	15		
Engineering and supervision			
Civil	75		
Mechanical	86		
Electrical	37		
	885		
Contingency			
Allowance for funds used during construction	240		
	240		

TABLE B-7. COSTS FOR HARRINGTON #2 PLANT
(Dollars × 10^3)

	Reported	Predicted[a]	Predicted[b]
Collector and supports	--	3,730	3,920
Ducting and supports	--	680	830
Insulation	--	1,150	1,210
ID fan	--	170	170
Miscellaneous	--	2,700	2,760
Engineering	--	1,690	1,780
Contingency	--	1,690	1,780
	11,100	11,800	12,450
Ash handling system	--	674	624
Engineering	--	135	125
Contingency	--	135	125
	2,810	944	874
	13,900	12,740	13,300

[a] One 356-MW baghouse.

[b] Two 178-MW baghouses.

TABLE B-8. COSTS FOR SHAWNEE PLANT
(Dollars × 10^3)

	Reported	Predicted[a]	Predicted[b]
Ten structural baghouses and all auxiliaries 1978-1981	80,000	74,000	63,200
Less 10 percent for retrofit	8,000		
	72,000		

[a] Ten 175-MW baghouses. Includes: Collector and supports, ducting and supports, ash removal system, insulation, ID fan, miscellaneous, engineering, contingency.

[b] One 1,750-MW baghouse (includes all items listed above).

Note

The following listings were prepared with an updated version of the COST program. While the format of these listings is different from the formats shown in Figures 18 and 19, the equations used to obtain the results are unchanged.

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1       PAGE 1 OF 3

PLANT : KRAMER2
DATE : 09/23/81
REMARKS : 3 SMALL BAGHOUSES (25 MW EACH)

                                  PLANT DATA
================================================================================
     BOILER SIZE                                          25 MW NET
     CAPACITY FACTOR                                    69.0 %
     CHEM. ENG. PLANT COST INDEX                       202.0
     EMISSION LIMIT                                      0.0 LB/MBTU
     PLANT ALTITUDE                                      973 FT
     INTEREST RATE                                     20.00 %/YR
     COST OF ELECTRICITY                               30.00 MIL/KWH
     CONTINGENCY AS PERCENT OF FIELD COST               20.0 %
     ENGINEERING AS PERCENT OF FIELD COST               20.0 %
     STEAM CYCLE EFFICIENCY                             38.0 %
     GAS FLOW RATE                                       122 KACFM
     BOILER EMISSIONS                                    0.0 LB/MBTU
     COAL HEATING VALUE                               10,911 BTU/LB
     FRACTION EXCESS AIR                                0.25
     PERCENT CARBON IN COAL                            67.50 %
     PERCENT HYDROGEN IN COAL                           5.30 %
     PERCENT OXYGEN IN COAL                            10.60 %
     PERCENT SULFUR IN COAL                             0.30 %
     PERCENT NITROGEN IN COAL                           1.51 %
     PERCENT ASH IN COAL                                4.20 %
     PERCENT WATER IN COAL                             11.00 %
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1       PAGE 2 OF 3
PLANT : KRAMER2
DATE : 09/23/81

BAGHOUSE NAME : BAG2
REMARKS : COST OF 3 SMALL BAGHOUSES
                                  BAGHOUSE DATA
================================================================================
     GAS TEMPERATURE                                       365 F
     EXPECTED BAGHOUSE LIFE                                 20 YRS
     AIR TO CLOTH RATIO                                  1.690 FT/MIN
     MAXIMUM PRESSURE DROP                                6.00 IN H2O
     AVERAGE PRESSURE DROP                                4.50 IN H2O
     NUMBER OF MODULES                                      10
     REVERSE AIR FAN SIZE (KW/10E5 M2 BAG AREA)            165
     BAG LIFE                                              2.0 YEARS
     BAG LIFE EXPONENT                                   0.600
     BAG REPLACEMENT COST                             $   0.65 /FT2
     LABOR RATE                                       $  14.00 /HR
     MATERIAL OVERHEAD FRACTION                          0.100
     FAN LOAD FACTOR                                     0.820
     FAN EFFICIENCY                                       80.0 %
     HOPPER HEATER DUTY FACTOR                           0.300
     ACCESORIES DUTY FACTOR                              0.800
     ASH REMOVAL SYSTEM DUTY FACTOR                      0.600
     SCHEDULED BAG REPLACEMENT TIME                          2 MIN/M2
     UNSCHEDULED BAG REPLACEMENT TIME                        7 MIN/M2
     FRACTION OF UNSCHEDULED BAG REPLACEMENTS            0.050
     NON BAG MAINTENANCE TIME (HR/YR/1000 CMS)             560
```

```
     M PARTICULATE CONTROL COST MODEL VERSION 1.1            PAGE 3 OF 3
PLANT : KRAMER2
DATE : 09/23/81

BAGHOUSE NAME : BAG2
REMARKS : COST OF 3 SMALL BAGHOUSES

                                   RESULTS
*******************************************************************************

        COLLECTOR & SUPPORTS                       $ 7.10E+05
        DUCTING & SUPPORTS                         $ 1.05E+05
        ASH REMOVAL SYSTEM                         $ 9.93E+04
        INSULATION                                 $ 2.39E+05
        ASH POND                                   $ 9.99E+04
        ID FAN                                     $ 1.26E+04
        MISCELLANEOUS                              $ 4.04E+05
        TOTAL FIELD COST...................................$ 1.67E+06
        ENGINEERING                                $ 3.34E+05
        CONTINGENCY                                $ 3.34E+05
        TURN-KEY COST......................................$ 2.34E+06

        FIXED OPERATING COSTS                      $ 7.52E+04
        VARIABLE OPERATING COSTS                   $ 3.09E+04
        COST OF ELECTRICITY                        $ 2.77E+04
        ANNUAL CAPITAL COST................................$ 4.80E+05
        TOTAL ANNUAL COST..................................$ 6.14E+05
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1       PAGE 1 OF 3

PLANT : NAVAJO1
DATE : 09/25/81
REMARKS : COMPARISON WITH ACTUAL COST

                                   PLANT DATA
===============================================================================
     BOILER SIZE                                          750 MW NET
     CAPACITY FACTOR                                     70.0 %
     CHEM. ENG. PLANT COST INDEX                        202.0
     EMISSION LIMIT                                       0.1 LB/MBTU
     PLANT ALTITUDE                                       984 FT
     INTEREST RATE                                      20.00 %/YR
     COST OF ELECTRICITY                                30.00 MIL/KWH
     CONTINGENCY AS PERCENT OF FIELD COST                20.0 %
     ENGINEERING AS PERCENT OF FIELD COST                20.0 %
     STEAM CYCLE EFFICIENCY                              38.0 %
     GAS FLOW RATE                                      3,940 KACFM
     BOILER EMISSIONS                                     0.0 LB/MBTU
     COAL HEATING VALUE                                11,000 BTU/LB
     FRACTION EXCESS AIR                                 0.25
     PERCENT CARBON IN COAL                             61.00 %
     PERCENT HYDROGEN IN COAL                            4.40 %
     PERCENT OXYGEN IN COAL                             12.00 %
     PERCENT SULFUR IN COAL                              0.45 %
     PERCENT NITROGEN IN COAL                            1.00 %
     PERCENT ASH IN COAL                                 7.00 %
     PERCENT WATER IN COAL                              10.00 %
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1       PAGE 2 OF 3
PLANT : NAVAJO1
DATE : 09/25/81

ESP NAME : UNIT3
REMARKS : HOTSIDE ESP
                                     ESP DATA
===============================================================================
     GAS TEMPERATURE                                      662  F
     EXPECTED ESP LIFE                                     20 YRS
     CURRENT DENSITY                                    40.00 NA/CM[2
     FLYASH RESISTIVITY                               5.0E+09 OHM CM
     SPECIFIC COLLECTION AREA                          307.00 FT2/KACFM
     ESP PRESSURE DROP                                   2.95 IN. H20
     FAN LOAD FACTOR (0<>1)                              0.82
     FAN EFFICIENCY                                     80.00 %
     HOPPER HEATER POWER                                10.00 KW/HOPPER
     HOPPER HEATER DUTY FACTOR (0<>1)                    0.30
     ACCESORIES DUTY FACTOR (0<>1)                       0.80
     ASH REMOVAL SYSTEM DUTY FACTOR (0<>1)               0.60
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1       PAGE 3 OF 3
PLANT : NAVAJO1
DATE : 09/25/81

ESP NAME : UNIT3
REMARKS : HOTSIDE ESP

                                    RESULTS
******************************************************************************

        COLLECTOR & SUPPORTS                     $ 7.82E+06
        DUCTING & SUPPORTS                       $ 5.07E+06
        ASH REMOVAL SYSTEM                       $ 6.03E+05
        INSULATION                               $ 1.79E+06
        ASH POND                                 $ 9.70E+05
        ID FAN                                   $ 1.36E+05
        MISCELLANEOUS                            $ 1.01E+07
        TOTAL FIELD COST.....................................$ 2.65E+07
        ENGINEERING                              $ 5.30E+06
        CONTINGENCY                              $ 5.30E+06
        TURN-KEY COST........................................$ 3.71E+07

        FIXED OPERATING COSTS                    $ 7.52E+04
        VARIABLE OPERATING COSTS                 $ 1.47E+05
        COST OF ELECTRICITY                      $ 5.32E+05
        ANNUAL CAPITAL COST..................................$ 7.62E+06
        TOTAL ANNUAL COST....................................$ 8.37E+06
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1        PAGE 1 OF 3

PLANT : KRAMER
DATE : 09/23/81
REMARKS : COMPARISON WITH ACTUAL COSTS

                                   PLANT DATA
================================================================================
     BOILER SIZE                                         115 MW NET
     CAPACITY FACTOR                                    69.0 %
     CHEM. ENG. PLANT COST INDEX                       202.0
     EMISSION LIMIT                                      0.0 LB/MBTU
     PLANT ALTITUDE                                      973 FT
     INTEREST RATE                                     20.00 %/YR
     COST OF ELECTRICITY                               30.00 MIL/KWH
     CONTINGENCY AS PERCENT OF FIELD COST               20.0 %
     ENGINEERING AS PERCENT OF FIELD COST               20.0 %
     STEAM CYCLE EFFICIENCY                             38.0 %
     GAS FLOW RATE                                       558 KACFM
     BOILER EMISSIONS                                    0.0 LB/MBTU
     COAL HEATING VALUE                               10,911 BTU/LB
     FRACTION EXCESS AIR                                0.25
     PERCENT CARBON IN COAL                            67.50 %
     PERCENT HYDROGEN IN COAL                           5.30 %
     PERCENT OXYGEN IN COAL                            10.60 %
     PERCENT SULFUR IN COAL                             0.30 %
     PERCENT NITROGEN IN COAL                           1.51 %
     PERCENT ASH IN COAL                                4.20 %
     PERCENT WATER IN COAL                             11.00 %
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1        PAGE 2 OF 3
PLANT : KRAMER
DATE : 09/23/81

BAGHOUSE NAME : BAG1
REMARKS : ONE LARGE BAGHOUSE
                                    BAGHOUSE DATA
================================================================================
     GAS TEMPERATURE                                     365 F
     EXPECTED BAGHOUSE LIFE                               20 YRS
     AIR TO CLOTH RATIO                                1.690 FT/MIN
     MAXIMUM PRESSURE DROP                              6.00 IN H2O
     AVERAGE PRESSURE DROP                              4.50 IN H2O
     NUMBER OF MODULES                                    46
     REVERSE AIR FAN SIZE (KW/10E5 M2 BAG AREA)          165
     BAG LIFE                                            2.0 YEARS
     BAG LIFE EXPONENT                                 0.600
     BAG REPLACEMENT COST                           $   0.65 /FT2
     LABOR RATE                                     $  14.00 /HR
     MATERIAL OVERHEAD FRACTION                        0.100
     FAN LOAD FACTOR                                   0.820
     FAN EFFICIENCY                                     80.0 %
     HOPPER HEATER DUTY FACTOR                         0.300
     ACCESORIES DUTY FACTOR                            0.800
     ASH REMOVAL SYSTEM DUTY FACTOR                    0.600
     SCHEDULED BAG REPLACEMENT TIME                        2 MIN/M2
     UNSCHEDULED BAG REPLACEMENT TIME                      7 MIN/M2
     FRACTION OF UNSCHEDULED BAG REPLACEMENTS          0.050
     NON BAG MAINTENANCE TIME (HR/YR/1000 CMS)           560
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1        PAGE 3 OF 3
PLANT : KRAMER
DATE : 09/23/81

BAGHOUSE NAME : BAG1
REMARKS : ONE LARGE BAGHOUSE

                                    RESULTS
********************************************************************************

        COLLECTOR & SUPPORTS                      $ 2.92E+06
        DUCTING & SUPPORTS                        $ 3.13E+05
        ASH REMOVAL SYSTEM                        $ 5.39E+05
        INSULATION                                $ 9.69E+05
        ASH POND                                  $ 2.43E+05
        ID FAN                                    $ 5.74E+04
        MISCELLANEOUS                             $ 1.77E+06
        TOTAL FIELD COST..................................$ 6.81E+06
        ENGINEERING                               $ 1.36E+06
        CONTINGENCY                               $ 1.36E+06
        TURN-KEY COST.....................................$ 9.54E+06

        FIXED OPERATING COSTS                     $ 7.52E+04
        VARIABLE OPERATING COSTS                  $ 1.46E+05
        COST OF ELECTRICITY                       $ 1.27E+05
        ANNUAL CAPITAL COST...............................$ 1.96E+06
        TOTAL ANNUAL COST.................................$ 2.31E+06
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1        PAGE 1 OF 3

PLANT : KRAMER3
DATE : 09/23/81
REMARKS : ONE 40 MW BOILER

                                PLANT DATA
================================================================================
     BOILER SIZE                                           40 MW NET
     CAPACITY FACTOR                                     69.0 %
     CHEM. ENG. PLANT COST INDEX                        202.0
     EMISSION LIMIT                                       0.0 LB/MBTU
     PLANT ALTITUDE                                       973 FT
     INTEREST RATE                                      20.00 %/YR
     COST OF ELECTRICITY                                30.00 MIL/KWH
     CONTINGENCY AS PERCENT OF FIELD COST                20.0 %
     ENGINEERING AS PERCENT OF FIELD COST                20.0 %
     STEAM CYCLE EFFICIENCY                              38.0 %
     GAS FLOW RATE                                        192 KACFM
     BOILER EMISSIONS                                     0.0 LB/MBTU
     COAL HEATING VALUE                                10,911 BTU/LB
     FRACTION EXCESS AIR                                 0.25
     PERCENT CARBON IN COAL                             67.50 %
     PERCENT HYDROGEN IN COAL                            5.30 %
     PERCENT OXYGEN IN COAL                              1.60 %
     PERCENT SULFUR IN COAL                              0.30 %
     PERCENT NITROGEN IN COAL                            1.50 %
     PERCENT ASH IN COAL                                 4.20 %
     PERCENT WATER IN COAL                              11.00 %


OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1        PAGE 2 OF 3
PLANT : KRAMER3
DATE : 09/23/81

BAGHOUSE NAME : BAG3
REMARKS : ONE 40 MW BAGHOUSE
                                 BAGHOUSE DATA
================================================================================
     GAS TEMPERATURE                                      365 F
     EXPECTED BAGHOUSE LIFE                                20 YRS
     AIR TO CLOTH RATIO                                 1.690 FT/MIN
     MAXIMUM PRESSURE DROP                               6.00 IN H2O
     AVERAGE PRESSURE DROP                               4.50 IN H2O
     NUMBER OF MODULES                                     16
     REVERSE AIR FAN SIZE (KW/10E5 M2 BAG AREA)           165
     BAG LIFE                                             2.0 YEARS
     BAG LIFE EXPONENT                                  0.600
     BAG REPLACEMENT COST                             $  0.65 /FT2
     LABOR RATE                                       $ 14.00 /HR
     MATERIAL OVERHEAD FRACTION                         0.100
     FAN LOAD FACTOR                                    0.820
     FAN EFFICIENCY                                      80.0 %
     HOPPER HEATER DUTY FACTOR                          0.300
     ACCESORIES DUTY FACTOR                             0.800
     ASH REMOVAL SYSTEM DUTY FACTOR                     0.600
     SCHEDULED BAG REPLACEMENT TIME                         2 MIN/M2
     UNSCHEDULED BAG REPLACEMENT TIME                       7 MIN/M2
     FRACTION OF UNSCHEDULED BAG REPLACEMENTS           0.050
     NON BAG MAINTENANCE TIME (HR/YR/1000 CMS)            560


OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1        PAGE 3 OF 3
PLANT : KRAMER3
DATE : 09/23/81

BAGHOUSE NAME : BAG3
REMARKS : ONE 40 MW BAGHOUSE

                                   RESULTS
*******************************************************************************

        COLLECTOR & SUPPORTS                   $ 1.09E+06
        DUCTING & SUPPORTS                     $ 1.45E+05
        ASH REMOVAL SYSTEM                     $ 1.66E+05
        INSULATION                             $ 3.64E+05
        ASH POND                               $ 1.31E+05
        ID FAN                                 $ 1.98E+04
        MISCELLANEOUS                          $ 6.29E+05
        TOTAL FIELD COST.................................$ 2.54E+06
        ENGINEERING                            $ 5.09E+05
        CONTINGENCY                            $ 5.09E+05
        TURN-KEY COST....................................$ 3.56E+06

        FIXED OPERATING COSTS                  $ 7.52E+04
        VARIABLE OPERATING COSTS               $ 4.87E+04
        COST OF ELECTRICITY                    $ 4.39E+04
        ANNUAL CAPITAL COST..............................$ 7.31E+05
        TOTAL ANNUAL COST................................$ 8.99E+05
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1        PAGE 1 OF 3

PLANT : GEORGE NEAL
DATE : 09/24/81
REMARKS : COMPARISON WITH ACTUAL COSTS

                                PLANT DATA
==============================================================================
     BOILER SIZE                                        530 MW NET
     CAPACITY FACTOR                                   70.0 %
     CHEM. ENG. PLANT COST INDEX                      182.4
     EMISSION LIMIT                                     0.1 LB/MBTU
     PLANT ALTITUDE                                   1000 FT
     INTEREST RATE                                    20.00 %/YR
     COST OF ELECTRICITY                              30.00 MIL/KWH
     CONTINGENCY AS PERCENT OF FIELD COST             20.0 %
     ENGINEERING AS PERCENT OF FIELD COST             20.0 %
     STEAM CYCLE EFFICIENCY                           38.0 %
     GAS FLOW RATE                                    2,004 KACFM
     BOILER EMISSIONS                                   0.0 LB/MBTU
     COAL HEATING VALUE                               9,993 BTU/LB
     FRACTION EXCESS AIR                               0.25
     PERCENT CARBON IN COAL                           59.20 %
     PERCENT HYDROGENIN COAL                          4.33 %
     PERCENT OXYGEN IN COAL                           17.00 %
     PERCENT SULFUR IN COAL                            0.53 %
     PERCENT NITROGEN IN COAL                          0.75 %
     PERCENT ASH IN COAL                              11.00 %
     PERCENT WATER IN COAL                             7.00 %
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1        PAGE 2 OF 3
PLANT : GEORGE NEAL

ESP NAME : NUM3
REMARKS : ONE LARGE ESP
                                  ESP DATA
==============================================================================
     GAS TEMPERATURE                                    254  F
     EXPECTED ESP LIFE                                   20 YRS
     CURRENT DENSITY                                  20.00 NA/CM2
     FLYASH RESISTIVITY                              2.0E+10 OHM CM
     SPECIFIC COLLECTION AREA                        800.00 FT2/KACFM
     ESP PRESSURE DROP                                 2.50 IN. H20
     FAN LOAD FACTOR (0<>1)                            0.82
     FAN EFFICIENCY                                   80.00 %
     HOPPER HEATER POWER                              10.00 KW/HOPPER
     HOPPER HEATER DUTY FACTOR (0<>1)                  0.30
     ACCESORIES DUTY FACTOR (0<>1)                     0.80
     ASH REMOVAL SYSTEM DUTY FACTOR (0<>1)             0.60
```

```
      PAGE 3 OF 3
PLANT : GEORGE NEAL
DATE : 09/24/81

ESP NAME : NUM3
REMARKS : ONE LARGE ESP

                                RESULTS
******************************************************************************

       COLLECTOR & SUPPORTS                      $1.01E+07
       DUCTING & SUPPORTS                        $ 2.79E+06
       ASH REMOVAL SYSTEM                        $ 1.21E+06
       INSULATION                                $ 1.16E+06
       ASH POND                                  $ 9.90E+05
       ID FAN                                    $ 8.07E+04
       MISCELLANEOUS                             $ 6.32E+06
       TOTAL FIELD COST...................................$ 2.26E+07
       ENGINEERING                               $ 4.52E+06
       CONTINGENCY                               $ 4.52E+06
       TURN-KEY COST......................................$ 3.17E+07

       FIXED OPERATING COSTS                     $ 6.79E+04
       ARIABLE OPERATING COSTS                  $ 1.29E+05
       COST OF ELECTRICITY                       $ 6.12E+05
       ANNUAL CAPITAL COST................................$ 6.50E+06
       TOTAL ANNUAL COST.................................$ 7.21E+06
```

```
OTPUT FROM PARTICULATE CONTROL COST MODEL VERSON 1.1     PAGE 1 OF 3

PLANT : GE03
DATE : 09/24/81
REMARKS : COMPARISON WITH ACTUAL COSTS

                              PLANT DATA
**********************************************************************
    BOILER SIZE                                  265 MW NET
     CAPACITY FACTOR                              70.0 %
     CHEM. ENG. PLANT COST INDEX                 182.4
     EMISSION LIMIT                                0.1 LB/MBTU
     PLANT ALTITUDE                               1000 FT
     INTEREST RATE                                20.00 %/YR
     COST OF ELECTRICITY                          30.00 MIL/KWH
     CONTINGENCY AS PERCENT OF FIELD COST         20.0 %
     ENGINEERING AS PERCENT OF FIELD COST         20.0 %
     STEAMCYCLE EFFICIENCY                       38.0 %
     GAS FLOW RATE                               1,042 KACFM
     BOILER EMISSIONS                              0.0 LB/MBTU
     COAL HEATING VALUE                         10,000 BTU/LB
     FRACTION EXCESS AIR                          0.25
     PERCENT CARBON IN COAL                      59.20 %
     PERCENT HYDROGEN IN COAL                     4.33 %
     PERCENT OXYGEN IN COAL                      17.00 %
     PERCENT SULFUR IN COAL                       0.53 %
     PERCENT NITROGEN IN COAL                     0.75 %
     PERCENT ASH IN COAL                         11.00 %
     PERCENT WATER IN COAL                       7.60 %
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1       PAGE 2 OF 3
PLANT : GE03
DATE : 09/24/81

ESP NAME : UNIT3
REMARKS : 2 SMALL ESPS
                              ESP DAT
**********************************************************************
F
     EXPECTED ESP LIFE                              20 YRS
     CURRENT DENSITY                             20.00 NA/CM 2
     FLYASH RESISTIVITY                        2.0E+10 OHM CM
     SPECIFIC COLLECTION AREA                   800.00 FT2/KACFM
     ESP PRESSURE DROP                            2.50 IN. H20
     FAN LOAD FACTOR (0○1)                        0.82
     FAN EFFICIENCY                              80.00 %
     HOPPER HEATER POWER                         10.00 KW/HOPPER
     HOPPER HEATER DUTY FACTOR (0○1)              0.30
     ACCESSORIES DUTY FACTOR (0○1)                [illegible]
```

```
. OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1       PAGE 3 OF 3
[illegible]/81

ESP NAME : UNIT3
REMARKS : 2 SMALL ESPS

                              RESULTS
**********************************************************************

        COLLECTOR & SUPPORTS                 $ 5.14E+06
        DUCTING & SUPPORTS                   $ 1.57E+06
        ASH REMOVAL SYSTEM                   $ 7.05E+05
        INSULATION                           $ 5.90E+05
        ASH POND                             $ 6.60E+05
        ID FAN                               $ 4.04E+04
        MISCELLANEOUS                        $ 3.12E+06
        TOTAL FIELD COST...................................$ 1.18E+07
        ENGINEERING                          $ 2.36E+06
        CONTINGENCY                          $ 2.36E+06
        TURN-KEY COST......................................$ 1.65E+07

        FIXED OPERATING COSTS                $ 6.79E+04
        VARIABLE OPERATING COSTS             $ 6.81E+04
        COST OF ELECTRICITY                  $ 3.06E+05
        ANNUAL CAPITAL COST................................$ 3.40E+06
        TOTAL ANNUAL COST..................................$ 3.84E+06
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1        PAGE 1 OF 3

PLANT : SHAWNEE2
DATE : 09/24/81
REMARKS : COMPARISON WITH ACTUAL COSTS

                              PLANT DATA
================================================================================
     BOILER SIZE                                         175 MW NET
     CAPACITY FACTOR                                    90.0 %
     CHEM. ENG. PLANT COST INDEX                       215.0
     EMISSION LIMIT                                      0.0 LB/MBTU
     PLANT ALTITUDE                                      984 FT
     INTEREST RATE                                     20.00 %/YR
     COST OF ELECTRICITY                               30.00 MIL/KWH
     CONTINGENCY AS PERCENT OF FIELD COST               20.0 %
     ENGINEERING AS PERCENT OF FIELD COST               20.0 %
     STEAM CYCLE EFFICIENCY                             38.0 %
     GAS FLOW RATE                                       650 KACFM
     BOILER EMISSIONS                                    0.0 LB/MBTU
     COAL HEATING VALUE                                8,075 BTU/LB
     FRACTION EXCESS AIR                                0.25
     PERCENT CARBON IN COAL                            60.00 %
     PERCENT HYDROGEN IN COAL                           5.40 %
     PERCENT OXYGEN IN COAL                            11.20 %
     PERCENT SULFUR IN COAL                             0.33 %
     PERCENT NITROGEN IN COAL                           1.60 %
     PERCENT ASH IN COAL                                7.44 %
     PERCENT WATER IN COAL                             30.20 %
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1        PAGE 2 OF 3
PLANT : SHAWNEE2
DATE : 09/24/81

BAGHOUSE NAME : BAG2
REMARKS : 10 175 MW BAGHOUSES
                              BAGHOUSE DATA
================================================================================
     GAS TEMPERATURE                                     325 F
     EXPECTED BAGHOUSE LIFE                               20 YRS
     AIR TO CLOTH RATIO                                1.960 FT/MIN
     MAXIMUM PRESSURE DROP                              6.00 IN H2O
     AVERAGE PRESSURE DROP                              4.50 IN H2O
     NUMBER OF MODULES                                    10
     REVERSE AIR FAN SIZE (KW/10E5 M2 BAG AREA)          240
     BAG LIFE                                            2.0 YEARS
     BAG LIFE EXPONENT                                 0.600
     BAG REPLACEMENT COST                           $   0.65 /FT2
     LABOR RATE                                     $  14.00 /HR
     MATERIAL OVERHEAD FRACTION                        0.100
     FAN LOAD FACTOR                                   0.820
     FAN EFFICIENCY                                     80.0 %
     HOPPER HEATER DUTY FACTOR                         0.300
     ACCESORIES DUTY FACTOR                            0.800
     ASH REMOVAL SYSTEM DUTY FACTOR                    0.600
     SCHEDULED BAG REPLACEMENT TIME                        2 MIN/M2
     UNSCHEDULED BAG REPLACEMENT TIME                      7 MIN/M2
     FRACTION OF UNSCHEDULED BAG REPLACEMENTS          0.050
     NON BAG MAINTENANCE TIME (HR/YR/1000 CMS)           560
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1        PAGE 3 OF 3
PLANT : SHAWNEE2
DATE : 09/24/81

BAGHOUSE NAME : BAG2
REMARKS : 10 175 MW BAGHOUSES

                              RESULTS
*******************************************************************************

        COLLECTOR & SUPPORTS                    $ 2.28E+06
        DUCTING & SUPPORTS                      $ 3.72E+05
        ASH REMOVAL SYSTEM                      $ 2.40E+05
        INSULATION                              $ 6.52E+05
        ASH POND                                $ 6.40E+05
        ID FAN                                  $ 7.12E+04
        MISCELLANEOUS                           $ 1.49E+06
        TOTAL FIELD COST...................................$ 5.74E+06
        ENGINEERING                             $ 1.15E+06
        CONTINGENCY                             $ 1.15E+06
        TURN-KEY COST......................................$ 8.04E+06

        FIXED OPERATING COSTS                   $ 8.00E+04
        VARIABLE OPERATING COSTS                $ 2.07E+05
        COST OF ELECTRICITY                     $ 1.48E+05
        ANNUAL CAPITAL COST................................$ 1.65E+06
        TOTAL ANNUAL COST..................................$ 2.09E+06
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1        PAGE 1 OF 3
PLANT : SHAWNEE1
DATE : 09/24/81
REMARKS : COMPARISON WITH ACTUAL COSTS

                                      PLANT DATA
===============================================================================
       BOILER SIZE                                         1750 MW NET
       CAPACITY FACTOR                                     90.0 %
       CHEM. ENG. PLANT COST INDEX                        215.0
       EMISSION LIMIT                                       0.0 LB/MBTU
       PLANT ALTITUDE                                       984 FT
       INTEREST RATE                                      20.00 %/YR
       COST OF ELECTRICITY                                30.00 MIL/KWH
       CONTINGENCY AS PERCENT OF FIELD COST                20.0 %
       ENGINEERING AS PERCENT OF FIELD COST                20.0 %
       STEAM CYCLE EFFICIENCY                              38.0 %
       GAS FLOW RATE                                      6,500 KACFM
       BOILER EMISSIONS                                     0.0 LB/MBTU
       COAL HEATING VALUE                                 8,075 BTU/LB
       FRACTION EXCESS AIR                                 0.25
       PERCENT CARBON IN COAL                             60.00 %
       PERCENT HYDROGEN IN COAL                            5.40 %
       PERCENT OXYGEN IN COAL                             11.20 %
       PERCENT SULFUR IN COAL                              0.33 %
       PERCENT NITROGEN IN COAL                            1.60 %
       PERCENT ASH IN COAL                                 7.44 %
       PERCENT WATER IN COAL                              30.20 %
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1        PAGE 3 OF 3
PLANT : SHAWNEE1
DATE : 09/24/81

BAGHOUSE NAME : BAG1
REMARKS : 1 VERY LARGE BAGHOUSE

                                        RESULTS
*******************************************************************************

          COLLECTOR & SUPPORTS                         $ 1.94E+07
          DUCTING & SUPPORTS                           $ 1.95E+06
          ASH REMOVAL SYSTEM                           $ 3.09E+06
          INSULATION                                   $ 5.42E+06
          ASH POND                                     $ 2.45E+06
          ID FAN                                       $ 7.12E+05
          MISCELLANEOUS                                $ 1.39E+07
          TOTAL FIELD COST.....................................$ 4.69E+07
          ENGINEERING                                  $ 9.38E+06
          CONTINGENCY                                  $ 9.38E+06
          TURN-KEY COST........................................$ 6.57E+07

          FIXED OPERATING COSTS                        $ 8.00E+04
          VARIABLE OPERATING COSTS                     $ 2.34E+06
          COST OF ELECTRICITY                          $ 1.48E+06
          ANNUAL CAPITAL COST..................................$ 1.35E+07
          TOTAL ANNUAL COST....................................$ 1.74E+07
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1        PAGE 2 OF 3
PLANT : SHAWNEE1
DATE : 09/24/81

BAGHOUSE NAME : BAG1
REMARKS : 1 VERY LARGE BAGHOUSE
                                     BAGHOUSE DATA
===============================================================================
       GAS TEMPERATURE                                      325 F
       EXPECTED BAGHOUSE LIFE                                20 YRS
       AIR TO CLOTH RATIO                                 1.960 FT/MIN
       MAXIMUM PRESSURE DROP                               6.00 IN H2O
       AVERAGE PRESSURE DROP                               4.50 IN H2O
       NUMBER OF MODULES                                   %100
       REVERSE AIR FAN SIZE (KW/10E5 M2 BAG AREA)           240
       BAG LIFE                                             2.0 YEARS
       BAG LIFE EXPONENT                                  0.600
       BAG REPLACEMENT COST                             $  0.65 /FT2
       LABOR RATE                                       $ 14.00 /HR
       MATERIAL OVERHEAD FRACTION                         0.100
       FAN LOAD FACTOR                                    0.820
       FAN EFFICIENCY                                      80.0 %
       HOPPER HEATER DUTY FACTOR                          0.300
       ACCESORIES DUTY FACTOR                             0.800
       ASH REMOVAL SYSTEM DUTY FACTOR                     0.600
       SCHEDULED BAG REPLACEMENT TIME                         2 MIN/M2
       UNSCHEDULED BAG REPLACEMENT TIME                       7 MIN/M2
       FRACTION OF UNSCHEDULED BAG REPLACEMENTS           0.050
       NON BAG MAINTENANCE TIME (HR/YR/1000 CMS)            560
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1          PAGE 1 OF 3

PLANT : HARR2
DATE : 09/24/81
REMARKS : COMPARISON WITH ACTUAL COSTS

                                   PLANT DATA
==============================================================================
     BOILER SIZE                                            178 MW NET
     CAPACITY FACTOR                                       70.0 %
     CHEM. ENG. PLANT COST INDEX                          202.0
     EMISSION LIMIT                                         0.1 LB/MBTU
     PLANT ALTITUDE                                         904 FT
     INTEREST RATE                                        20.00 %/YR
     COST OF ELECTRICITY                                  30.00 MIL/KWH
     CONTINGENCY AS PERCENT OF FIELD COST                  20.0 %
     ENGINEERING AS PERCENT OF FIELD COST                  20.0 %
     STEAM CYCLE EFFICIENCY                                38.0 %
     GAS FLOW RATE                                          825 KACFM
     BOILER EMISSIONS                                       0.0 LB/MBTU
     COAL HEATING VALUE                                  11,000 BTU/LB
     FRACTION EXCESS AIR                                   0.25
     PERCENT CARBON IN COAL                               60.00 %
     PERCENT HYDROGEN IN COAL                              5.40 %
     PERCENT OXYGEN IN COAL                               11.20 %
     PERCENT SULFUR IN COAL                                0.33 %
     PERCENT NITROGEN IN COAL                              1.60 %
     PERCENT ASH IN COAL                                   4.80 %
     PERCENT WATER IN COAL                                13.60 %


OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1          PAGE 2 OF 3
PLANT : HARR2
DATE : 09/24/81

BAGHOUSE NAME : BAG2
REMARKS : 2 SMALL BAGHOUSES
                                   BAGHOUSE DATA
==============================================================================
     GAS TEMPERATURE
     EXPECTED BAGHOUSE LIFE                                 313 F
     AIR TO CLOTH RATIO                                      20 YRS
     MAXIMUM PRESSURE DROP                                3.200 FT/MIN
     AVERAGE PRESSURE DROP                                 6.00 IN H2O
     NUMBER OF MODULES                                     4.50 IN H2O
     REVERSE AIR FAN SIZE (KW/10E5 M2 BAG AREA)              14
     BAG LIFE                                               240
     BAG LIFE EXPONENT                                      2.0 YEARS
     BAG REPLACEMENT COST                                 0.600
     LABOR RATE                                        $  0.65 /FT2
     MATERIAL OVERHEAD FRACTION                        $ 14.00 /HR
     FAN LOAD FACTOR                                      0.100
     FAN EFFICIENCY                                       0.820
     HOPER HEATER DTY FACTOR                               80.0 %
     ACCESORIES DUTY FACTOR                               0.300
     ASH REMOVAL SYSTEM DUTY FACTOR                       0.800
    SCEDULED BAG REPLACEMENT TIME                         0.600
     UNSCHEDULED BAG REPLACEMENT TIME                         2 MIN/M2
     FRACTION OF UNSCHEDULED BAG REPLACEMENTS                 7 MIN/M2
   . NON BAG MAINTENANCE TIME (HR/YR/1000 CMS)            0.050
                                                            560


OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1          PAGE 3 OF 3
PLANT : HARR2
DATE : 09/24/81

BAGHOUSE NAME : BAG2
REMARKS : 2 SMALL BAGHOUSES

                                   RESULTS
******************************************************************************

       CLLE UPPORTS                      $ 1.96E+06
       DUCTING & SUPPORTS                          $ 4.15E+05
       ASH REMOVAL SYSTEM                          $ 3.12E+05
       INSULATION                                  $ 6.06E+05
       ASH POND                                    $ 3.35E+05
       ID FAN                                      $ 8.49E+04
       MISCELLANEOUS                               $ 1.38E+06
       TOTAL FIELD COST....................................$ 5.09E+06
       ENGINEERING                                 $ 1.02E+06
       CONTINGENCY                                 $ 1.02E+06
       TURN-KEY COST.......................................$ 7.12E+06
       FIXED OPERATING COSTS                       $ 7.52E+04
       VARIABLE OPERATING COSTS                    $ 1.50E+05
       COST OF ELECTRICITY                         $ 1.36E+05
       ANNUAL CAPITAL COST.................................$ 1.46E+06
       TOTAL ANNUAL COST...................................$ 1.83E+06
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1       PAGE 1 OF 3

PLANT : HARRINGTON
DATE : 09/24/81
REMARKS : COMPARISON WITH ACTUAL COSTS

                                PLANT DATA
==============================================================================
     BOILER SIZE                                    356 MW NET
     CAPACITY FACTOR                               70.0 %
     CHEM. ENG. PLANT COST INDEX                  202.0
     EMISSION LIMIT                                 0.1 LB/MBTU
     PLANT ALTITUDE                                 904 FT
     INTEREST RATE                                20.00 %/YR
     COST OF ELECTRICITY                          30.00 MIL/KWH
     CONTINGENCY AS PERCENT OF FIELD COST          20.0 %
     ENGINEERING AS PERCENT OF FIELD COST          20.0 %
     STEAM CYCLE EFFICIENCY                        38.0 %
     GAS FLOW RATE                                1.650 KACFM
     BOILER EMISSIONS                               0.0 LB/MBTU
     COAL HEATING VALUE                          11.000 BTU/LB
     FRACTION EXCESS AIR                           0.25
     PERCENT CARBON IN COAL                       60.00 %
     PERCENT HYDROGEN IN COAL                      5.40 %
     PERCENT OXYGEN IN COAL                       11.20 %
     PERCENT SULFUR IN COAL                        0.33 %
     PERCENT NITROGEN IN COAL                      0.30 %
     PERCENT ASH IN COAL                           4.80 %
     PERCENT WATER IN COAL                        13.60 %


OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1       PAGE 2 OF 3
PLANT : HARRINGTON
DATE : 09/24/81

BAGHOUSE NAME : BAG1
REMARKS : 1 LAE BGHOUSE
                                 BAGHOUSE DATA
==============================================================================
     GAS TEMPERATURE                                313 F
     EXPECTED BAGHOUSE LIFE                          20 YRS
     AIR TO CLOTH RATIO                           3.200 FT/MIN
     MAXIMUM PRESSURE DROP                         6.00 IN H2O
     AVERAGE PRESSURE DROP                         4.50 IN H2O
     NUMBER OF MODULES                               28
     REVERSE AIR FAN SIZE (KW/10E5 M2 BAG AREA)     240
     BAG LIFE                                       2.0 YEARS
     BAG LIFE EXPONENT                            0.600
     BAG REPLACEENT COST                      $  0.65 /FT2
     LABOR RATE                                 $ 14.00 /HR
     MATERIAL OVERHEAD FRACTION                   0.100
    N LOAD FACTOR                                .820
     FAN EFFICIENCY                                80.0 %
     HOPPER HEATER DUTY FACTOR                    0.300
     ACCESORIES DUTY FACTOR                       0.800
     ASH REMOVAL SYSTEM DUTY FACTOR               0.600
     SCHEDULED BAG REPLACEMENT TIME                   2 MIN/M2
     UNSCHEDULED BAG REPLACEMENT TIME                 7 MIN/M2


OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1:1       PAGE 3 OF 3
PLANT : HARRINGTON
DATE : 09/24/81

BAGHOUSE NAME : BAG1
REMARKS : 1 LARGE BAGHOUSE

                                  RESULTS
******************************************************************************
        COLLECTOR & SUPPORTS                 $ 3.73E+06
        DUCTING & SUPPORTS                   $ 6.04E+05
        ASH REMOVAL SYSTEM                   $ 6.74E+05
      INSULATION                           $ 1.15E+06
        ASH POND                             $ 5.02E+05
        ID FAN                               $ 1.70E+05
        MISCELLANEOUS                        $ 2.70E+06
        TOTAL FIELD COST.....................................$ 9.60E+06
        ENGINEERING                          $ 1.92E+06
        CONTINGENCY                          $ 1.92E+06
        TURN-KEY COST........................................$ 1.34E+07

        FIXED OPERATING COSTS                $ 7.52E+04
        VARIABLE OPERATING COSTS             $ 3.24E+05
        COST OF ELECTRICITY                  $ 2.72E+05
        ANNUAL CAPITAL COST..................................$ 2.76E+06
        TOTAL ANNUAL COST....................................$ 3.43E+06
```

```
                              COST MODEL VERSION 1.1        PAGE 1 OF 3

PLANT : NUCLA2
DATE : 09/23/81
REMARKS : 3 SMALL BAGHOUSES

                                   PLANT DATA
================================================================================
     BOILER SIZE                                              12 MW NET
     CAPACITY FACTOR                                        70.0 %
     CHEM. ENG. PLANT COST INDEX                           165.4
     EMISSION LIMIT                                          0.0 LB/MBTU
     PLANT ALTITUDE                                         1000 FT
     INTEREST RATE                                         20.00 %/YR
     COST OF ELECTRICITY                                   30.00 MIL/KWH
     CONTINGENCY AS PERCENT OF FIELD COST                   20.0 %
     ENGINEERING AS PERCENT OF FIELD COST                   20.0 %
     STEAM CYCLE EFFICIENCY                                 38.0 %
     GAS FLOW RATE                                            86 KACFM
     BOILER EMISSIONS                                        0.0 LB/MBTU
     COAL HEATING VALUE                                   12,000 BTU/LB
     FRACTION EXCESS AIR                                    0.25
     PERCENT CARBON IN COAL                                58.60 %
     PERCENT HYDROGEN IN COAL                               4.50 %
     PERCENT OXYGEN IN COAL                                16.00 %
     PERCENT SULFUR IN COAL                                 0.74 %
     PERCENT NITROGEN IN COAL                               0.97 %
     PERCENT ASH IN COAL                                   14.00 %
     PERCENT WATER IN COAL                                  5.20 %
```

```
BAGHOUSE NAME : BAG2
REMARKS : 3 SMALL BAGHOUSES
                                    BAGHOUSE DATA
================================================================================
     GAS TEMPERATURE                                           360 F
     EXPECTED BAGHOUSE LIFE                                     20 YRS
     AIR TO CLOTH RATIO                                      2.800 FT/MIN
     MAXIMUM PRESSURE DROP                                    8.00 IN H2O
     AVERAGE PRESSURE DROP                                    4.00 IN H2O
     NUMBER OF MODULES                                           6
     REVERSE AIR FAN SIZE (KW/10[5 M2 BAG AREA)                782
     BAG LIFE                                                  2.0 YEARS
     BAG LIFE EXPONENT                                       0.600
     BAG REPLACEMENT COST                                 $   0.65 /FT2
     LABOR RATE                                           $  14.00 /HR
     MATERIAL OVERHEAD FRACTION                              0.100
     FAN LOAD FACTOR                                         0.820
     FAN EFFICIENCY                                           80.0 %
     HOPPER HEATER DUTY FACTOR                               0.300
     ACCESORIES DUTY FACTOR                                  0.800
     ASH REMOVAL SYSTEM DUTY FACTOR                          0.600
     SCHEDULED BAG REPLACEMENT TIME                              2 MIN/M2
     UNSCHEDULED BAG REPLACEMENT TIME                            7 MIN/M2
     FRACTION OF UNSCHEDULED BAG REPLACEMENTS                0.050
     NON BAG MAINTENANCE TIME (HR/YR/1000 CMS)                 560
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1        PAGE 3 OF 3
PLANT : NUCLA2
DATE : 09/23/81

BAGHOUSE NAME : BAG2
REMARKS : 3 SMALL BAGHOUSES

                                    RESULTS
*******************************************************************************

        COLLECTOR & SUPPORTS                      $ 2.88E+05
        DUCTING & SUPPORTS                        $ 6.67E+04
        ASH REMOVAL SYSTEM                        $ 4.99E+04
        INSULATION                                $ 1.03E+05
        ASH POND                                  $ 1.03E+05
        ID FAN                                    $ 9.67E+03
        MISCELLANEOUS                             $ 1.74E+05
        TOTAL FIELD COST.....................................$ 7.95E+05
        ENGINEERING                               $ 1.59E+05
        CONTINGENCY                               $ 1.59E+05
        TURN-KEY COST........................................$ 1.11E+06

        FIXED OPERATING COSTS                     $ 6.15E+04
        VARIABLE OPERATING COSTS                  $ 1.82E+04
        COST OF ELECTRICITY                       $ 2.01E+04
        ANNUAL CAPITAL COST..................................$ 2.28E+05
        TOTAL ANNUAL COST....................................$ 3.28E+05
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1       PAGE 1 OF 3

PLANT : NUCLA1
DATE : 09/23/81
REMARKS : COMPARISON WITH ACTUAL COSTS (1 LARGE BAGHOUSE)

                                  PLANT DATA
================================================================================
     BOILER SIZE                                          36 MW NET
     CAPACITY FACTOR                                    70.0 %
     CHEM. ENG. PLANT COST INDEX                       165.4
     EMISSION LIMIT                                      0.0 LB/MBTU
     PLANT ALTITUDE                                     1000 FT
     INTEREST RATE                                     20.00 %/YR
     COST OF ELECTRICITY                               30.00 MIL/KWH
     CONTINGENCY AS PERCENT OF FIELD COST               20.0 %
     ENGINEERING AS PERCENT OF FIELD COST               20.0 %
     STEAM CYCLE EFFICIENCY                             38.0 %
     GAS FLOW RATE                                       258 KACFM
     BOILER EMISSIONS                                    0.0 LB/MBTU
     COAL HEATING VALUE                               12,000 BTU/LB
     FRACTION EXCESS AIR                                0.25
     PERCENT CARBON IN COAL                            58.60 %
     PERCENT HYDROGEN IN COAL                           4.50 %
     PERCENT OXYGEN IN COAL                            16.00 %
     PERCENT SULFUR IN COAL                             0.74 %
     PERCENT NITROGEN IN COAL                           0.97 %
     PERCENT ASH IN COAL                               14.00 %
     PERCENT WATER IN COAL                              5.20 %
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1       PAGE 2 OF 3
PLANT : NUCLA1
DATE : 09/23/81

BAGHOUSE NAME : BAG1
REMARKS : 1 LARGE BAGHOUSE
                                 BAGHOUSE DATA
================================================================================
     GAS TEMPERATURE                                     360 F
     EXPECTED BAGHOUSE LIFE                               20 YRS
     AIR TO CLOTH RATIO                                2.800 FT/MIN
     MAXIMUM PRESSURE DROP                              8.00 IN H2O
     AVERAGE PRESSURE DROP                              4.00 IN H2O
     NUMBER OF MODULES                                    18
     REVERSE AIR FAN SIZE (KW/10[5 M2 BAG AREA)          782
     BAG LIFE                                            2.0 YEARS
     BAG LIFE EXPONENT                                 0.600
     BAG REPLACEMENT COST                            $  0.65 /FT2
     LABOR RATE                                      $ 14.00 /HR
     MATERIAL OVERHEAD FRACTION                        0.100
     FAN LOAD FACTOR                                   0.820
     FAN EFFICIENCY                                     80.0 %
     HOPPER HEATER DUTY FACTOR                         0.300
     ACCESORIES DUTY FACTOR                            0.800
     ASH REMOVAL SYSTEM DUTY FACTOR                    0.600
     SCHEDULED BAG REPLACEMENT TIME                        2 MIN/M2
     UNSCHEDULED BAG REPLACEMENT TIME                      7 MIN/M2
     FRACTION OF UNSCHEDULED BAG REPLACEMENTS          0.050
     NON BAG MAINTENANCE TIME (HR/YR/1000 CMS)           560
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1       PAGE 3 OF 3
PLANT : NUCLA1
DATE : 09/23/81

BAGHOUSE NAME : BAG1
REMARKS : 1 LARGE BAGHOUSE

                                    RESULTS
********************************************************************************

        COLLECTOR & SUPPORTS                    $ 8.00E+05
        DUCTING & SUPPORTS                      $ 1.47E+05
        ASH REMOVAL SYSTEM                      $ 1.69E+05
        INSULATION                              $ 2.84E+05
        ASH POND                                $ 1.95E+05
        ID FAN                                  $ 2.90E+04
        MISCELLANEOUS                           $ 5.06E+05
        TOTAL FIELD COST..................................$ 2.13E+06
        ENGINEERING                             $ 4.26E+05
        CONTINGENCY                             $ 4.26E+05
        TURN-KEY COST.....................................$ 2.98E+06

        FIXED OPERATING COSTS                   $ 6.15E+04
        VARIABLE OPERATING COSTS                $ 5.36E+04
        COST OF ELECTRICITY                     $ 6.03E+04
        ANNUAL CAPITAL COST...............................$ 6.12E+05
        TOTAL ANNUAL COST.................................$ 7.88E+05
```

```
                                   PLANT DATA
================================================================================
     BOILER SIZE                                             175 MW NET
     CAPACITY FACTOR                                        70.0 %
     CHEM. ENG. PLANT COST INDEX                           144.0
     EMISSION LIMIT                                          0.0 LB/MBTU
     PLANT ALTITUDE                                         1000 FT
     INTEREST RATE                                         20.00 %/YR
     COST OF ELECTRICITY                                   30.00 MIL/KWH
     CONTINGENCY AS PERCENT OF FIELD COST                   20.0 %
     ENGINEERING AS PERCENT OF FIELD COST                   20.0 %
     STEAM CYCLE EFFICIENCY                                 38.0 %
     GAS FLOW RATE                                           888 KACFM
     BOILER EMISSIONS                                        0.0 LB/MBTU
     COAL HEATING VALUE                                    9,993 BTU/LB
     FRACTION EXCESS AIR                                    0.25
     PERCENT CARBON IN COAL                                60.00 %
     PERCENT HYDROGEN IN COAL                               5.40 %
     PERCENT OXYGEN IN COAL                                11.20 %
     PERCENT SULFUR IN COAL                                 0.60 %
     PERCENT NITROGEN IN COAL                               1.60 %
     PERCENT ASH IN COAL                                    7.60 %
     PERCENT WATER IN COAL                                 13.60 %


BAGHOUSE NAME : BAG1
REMARKS : 1 LARGE BAGHOUSE
                                 BAGHOUSE DATA
================================================================================
     GAS TEMPERATURE                                         300 F
     EXPECTED BAGHOUSE LIFE                                   20 YRS
     AIR TO CLOTH RATIO                                    2.000 FT/MIN
     MAXIMUM PRESSURE DROP                                  5.00 IN H2O
     AVERAGE PRESSURE DROP                                  2.50 IN H2O
     NUMBER OF MODULES                                        56
     REVERSE AIR FAN SIZE (KW/10E5 M2 BAG AREA)              240
     BAG LIFE                                                2.0 YEARS
     BAG LIFE EXPONENT                                     0.600
     BAG REPLACEMENT COST                               $   0.65 /FT2
     LABOR RATE                                         $  14.00 /HR
     MATERIAL OVERHEAD FRACTION                            0.100
     FAN LOAD FACTOR                                       0.820
     FAN EFFICIENCY                                         80.0 %
     HOPPER HEATER DUTY FACTOR                             0.300
     ACCESORIES DUTY FACTOR                                0.800
     ASH REMOVAL SYSTEM DUTY FACTOR                        0.600
     SCHEDULED BAG REPLACEMENT TIME                            2 MIN/M2
     UNSCHEDULED BAG REPLACEMENT TIME                          7 MIN/M2
     FRACTION OF UNSCHEDULED BAG REPLACEMENTS              0.050
     NON BAG MAINTENANCE TIME (HR/YR/1000 CMS)               560


DATE : 09/23/81

BAGHOUSE NAME : BAG1
REMARKS : 1 LARGE BAGHOUSE

                                    RESULTS
*******************************************************************************

       COLLECTOR & SUPPORTS                  $ 2.71E+06
       DUCTING & SUPPORTS                    $ 3.12E+05
       ASH REMOVAL SYSTEM                    $ 5.45E+05
       INSULATION                            $ 8.91E+05
       ASH POND                              $ 3.32E+05
       ID FAN                                $ 5.43E+04
       MISCELLANEOUS                         $ 1.72E+06
       TOTAL FIELD COST.................................$ 6.56E+06
       ENGINEERING                           $ 1.31E+06
       CONTINGENCY                           $ 1.31E+06
       TURN-KEY COST....................................$ 9.19E+06

       FIXED OPERATING COSTS                 $ 5.36E+04
       VARIABLE OPERATING COSTS              $ 2.15E+05
       COST OF ELECTRICITY                   $ 1.53E+05
       ANNUAL CAPITAL COST..............................$ 1.89E+06
       TOTAL ANNUAL COST................................$ 2.31E+06
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1        PAGE 1 OF 3

PLANT : SUNBURY2
DATE : 09/23/81
REMARKS : COMPARISON WITH ACTUAL COSTS

                                 PLANT DATA
================================================================================
     BOILER SIZE                                          44 MW NET
     CAPACITY FACTOR                                    70.0 %
     CHEM. ENG. PLANT COST INDEX                       144.0
     EMISSION LIMIT                                      0.0 LB/MBTU
     PLANT ALTITUDE                                     1000 FT
     INTEREST RATE                                     20.00 %/YR
     COST OF ELECTRICITY                               30.00 MIL/KWH
     CONTINGENCY AS PERCENT OF FIELD COST               20.0 %
     ENGINEERING AS PERCENT OF FIELD COST               20.0 %
     STEAM CYCLE EFFICIENCY                             38.0 %
     GAS FLOW RATE                                       222 KACFM
     BOILER EMISSIONS                                    0.0 LB/MBTU
     COAL HEATING VALUE                                9,993 BTU/LB
     FRACTION EXCESS AIR                                0.25
     PERCENT CARBON IN COAL                            60.00 %
     PERCENT HYDROGEN IN COAL                           5.40 %
     PERCENT OXYGEN IN COAL                            11.20 %
     PERCENT SULFUR IN COAL                             0.60 %
     PERCENT NITROGEN IN COAL                           1.60 %
     PERCENT ASH IN COAL                                7.60 %
     PERCENT WATER IN COAL                             13.60 %
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1        PAGE 2 OF 3
PLANT : SUNBURY2
DATE : 09/23/81

BAGHOUSE NAME : BAG2
REMARKS : 4 SMALL BAGHOUSES (44 MW EACH)
                                BAGHOUSE DATA
================================================================================
     GAS TEMPERATURE                                     302 F
     EXPECTED BAGHOUSE LIFE                               20 YRS
     AIR TO CLOTH RATIO                                2.073 FT/MIN
     MAXIMUM PRESSURE DROP                              5.00 IN H2O
     AVERAGE PRESSURE DROP                              2.50 IN H2O
     NUMBER OF MODULES                                    14
     REVERSE AIR FAN SIZE (KW/10E5 M2 BAG AREA)          240
     BAG LIFE                                            2.0 YEARS
     BAG LIFE EXPONENT                                 0.600
     BAG REPLACEMENT COST                           $   0.65 /FT2
     LABOR RATE                                     $  14.00 /HR
     MATERIAL OVERHEAD FRACTION                        0.100
     FAN LOAD FACTOR                                   0.820
     FAN EFFICIENCY                                     80.0 %
     HOPPER HEATER DUTY FACTOR                         0.300
     ACCESORIES DUTY FACTOR                            0.800
     ASH REMOVAL SYSTEM DUTY FACTOR                    0.600
     SCHEDULED BAG REPLACEMENT TIME                        2 MIN/M2
     UNSCHEDULED BAG REPLACEMENT TIME                      7 MIN/M2
     FRACTION OF UNSCHEDULED BAG REPLACEMENTS          0.050
     NON BAG MAINTENANCE TIME (HR/YR/1000 CMS)           560
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1        PAGE 3 OF 3
PLANT : SUNBURY2
DATE : 09/23/81

BAGHOUSE NAME : BAG2
REMARKS : 4 SMALL BAGHOUSES (44 MW EACH)

                                  RESULTS
*******************************************************************************

        COLLECTOR & SUPPORTS                      $ 7.28E+05
        DUCTING & SUPPORTS                        $ 1.15E+05
        ASH REMOVAL SYSTEM                        $ 1.17E+05
        INSULATION                                $ 2.44E+05
        ASH POND                                  $ 1.49E+05
        ID FAN                                    $ 1.36E+04
        MISCELLANEOUS                             $ 4.40E+05
        TOTAL FIELD COST...................................$ 1.81E+06
        ENGINEERING                               $ 3.61E+05
        CONTINGENCY                               $ 3.61E+05
        TURN-KEY COST......................................$ 2.53E+06

        FIXED OPERATING COSTS                     $ 5.36E+04
        VARIABLE OPERATING COSTS                  $ 5.08E+04
        COST OF ELECTRICITY                       $ 3.79E+04
        ANNUAL CAPITAL COST................................$ 5.19E+05
        TOTAL ANNUAL COST..................................$ 6.61E+05
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1       PAGE 1 OF 3

PLANT : PLANTA
DATE : 09/25/81
REMARKS : COMPARISON WITH ACTUAL COSTS

                                   PLANT DATA
================================================================================
     BOILER SIZE                                        576 MW NET
     CAPACITY FACTOR                                   70.0 %
     CHEM. ENG. PLANT COST INDEX                      182.0
     EMISSION LIMIT                                     0.1 LB/MBTU
     PLANT ALTITUDE                                     984 FT
     INTEREST RATE                                    20.00 %/YR
     COST OF ELECTRICITY                              30.00 MIL/KWH
     CONTINGENCY AS PERCENT OF FIELD COST              20.0 %
     ENGINEERING AS PERCENT OF FIELD COST              20.0 %
     STEAM CYCLE EFFICIENCY                            38.0 %
     GAS FLOW RATE                                    3,400 KACFM
     BOILER EMISSIONS                                   0.0 LB/MBTU
     COAL HEATING VALUE                               9,993 BTU/LB
     FRACTION EXCESS AIR                               0.25
     PERCENT CARBON IN COAL                           60.00 %
     PERCENT HYDROGEN IN COAL                          5.40 %
     PERCENT OXYGEN IN COAL                           11.20 %
     PERCENT SULFUR IN COAL                            0.60 %
     PERCENT NITROGEN IN COAL                          1.60 %
     PERCENT ASH IN COAL                               7.60 %
     PERCENT WATER IN COAL                            13.60 %
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1       PAGE 2 OF 3
PLANT : PLANTA
DATE : 09/25/81

ESP NAME : ESP2
REMARKS : HOTSIDE ESP
                                    ESP DATA
================================================================================
     GAS TEMPERATURE                                    650  F
     EXPECTED ESP LIFE                                   20 YRS
     CURRENT DENSITY                                  20.00 NA/CM[2
     FLYASH RESISTIVITY                             2.0E+10 OHM CM
     SPECIFIC COLLECTION AREA                        450.00 FT2/KACFM
     ESP PRESSURE DROP                                 2.95 IN. H20
     FAN LOAD FACTOR (0<>1)                            0.82
     FAN EFFICIENCY                                   80.00 %
     HOPPER HEATER POWER                              10.00 KW/HOPPER
     HOPPER HEATER DUTY FACTOR (0<>1)                  0.30
     ACCESORIES DUTY FACTOR (0<>1)                     0.80
     ASH REMOVAL SYSTEM DUTY FACTOR (0<>1)             0.60
```

```
OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1       PAGE 3 OF 3
PLANT : PLANTA
DATE : 09/25/81

ESP NAME : ESP2
REMARKS : HOTSIDE ESP

                                     RESULTS
********************************************************************************

        COLLECTOR & SUPPORTS                      $ 8.73E+06
        DUCTING & SUPPORTS                        $ 3.98E+06
        ASH REMOVAL SYSTEM                        $ 6.51E+05
        INSULATION                                $ 1.70E+06
        ASH POND                                  $ 8.33E+05
        ID FAN                                    $ 1.07E+05
        MISCELLANEOUS                             $ 9.53E+06
        TOTAL FIELD COST....................................$ 2.55E+07
        ENGINEERING                               $ 5.11E+06
        CONTINGENCY                               $ 5.11E+06
        TURN-KEY COST.......................................$ 3.57E+07

        FIXED OPERATING COSTS                     $ 6.77E+04
        VARIABLE OPERATING COSTS                  $ 1.60E+05
        COST OF ELECTRICITY                       $ 4.11E+05
        ANNUAL CAPITAL COST.................................$ 7.34E+06
        TOTAL ANNUAL COST...................................$ 7.98E+06
```

APPENDIX C
PROGRAM LISTINGS

```
10 REM PARTICULATE CONTROL TECHNOLOGY COST MODELS
20 REM WRITTEN FOR TRS-80 MODEL I DISK BASIC
30 REM REQUIRES DISK BASIC 1 DISK DRIVE AND 48K RAM
40 REM PROGRAM IS TOO LONG TO BE COMPLILED WITH MICROSOFT
50 REM BASIC COMPLILER
60 REM MAJOR INPUT MODULE FOR PARTICULATE COST MODELS
70 REM VERSION 1.1 BY L. E. SPARKS AND A. S. VINER  11 DEC 1980
80 REM LAST UPDATE 1 JUNE 1981
90 REM ************************************************
100 CLEAR 2000
110 A$="YN"
115 DEF FNW$(W$)=RIGHT$(W$,LEN(W$)-1)
120 TY$(1)="ESP"
:TY$(3)="ESP&SCRUBBER"
:TY$(2)="SCRUBBER"
:TY$(4)=" BAGHOUSE"
130 DIM F$(42),X(42),C(42),C$(42,2),Z$(42),R$(20)
140 CLS
:GOSUB 2060
:GOSUB 3440
150 X$=STR$(PEEK(16922))
:Y$=STR$(PEEK(16923))
:Z$=STR$(PEEK(16924) )
:DA$=FNW$(Z$)+"/"+FNW$(Y$)+"/"+FNW$(X$)
:DA$=LEFT$(DA$,8)
160 PRINT"DO YOU WANT INSTRUCTIONS (Y OR N) ?";
170 GOSUB 2140
180 IF X$="Y" THEN GOSUB 2550
190 CLS
:GOSUB 2060
200 REM NOW INPUT COMMON DATA
210 LINE INPUT"      PLANT NAME : ";P$
:F$=P$
:IF LEN(P$)=0 THEN 210
220 J%=LEN(F$)
:I%=INSTR(F$," ")
:IF I%=0 THEN 260
230 IF I%=1 THEN F$=RIGHT$(F$,J%-1)
:GOTO 220
240 IF I%=J% THEN F$=LEFT$(F$,J%-1)
:GOTO 220
250 F$=LEFT$(F$,I%-1)+RIGHT$(F$,J%-I%)
:GOTO 220
260 IF LEN(F$)>8 THEN F$=LEFT$(F$,4)+RIGHT$(F$,4)
270 LINE INPUT"      REMARKS : ";RE$
280 PRINT"CHECK FOR PLANT FILE"
:F$=F$+"/INP"
290 GOSUB 1860
: IF INSTR(Z$,P$)<>0 THEN PRINT"READING PLANT DATA"
: GOSUB 1730
: GOSUB 7240
300 M=0
```

```
:CN=0
:PRINT
: PRINT"DO YOU WANT ENGLISH OR METRIC UNITS (E OR M) ";
:GOSUB 2340
:UN$=X$
:PRINT X$
310 IF INSTR("EM",UN$)=0 THEN PRINT "ENTER E OR M PLEASE"
:GOTO 300
320 CLS
:IF INSTR(Z$,P$)<>0 THEN 550
330 GOSUB 3130
: GOSUB 3400
: IF UN$="E" THEN JS=1
: JF=21
: GOSUB2000
340 PN=1
:P=1
:NP=2
350 CLS
:PRINT STRING$(63,"=")
:PRINT"DATA FOR PLANT ";P$;
:PRINT USING"      PAGE ## OF ## ";PN,NP
:PRINT STRING$(63,"=")
360 IF PN=2 THEN JS=11 ELSE JS=1
:MX=10
370 IF PN=1 THEN JF=10 ELSE JF=21
:MX=11
380 FOR J%=JSTO JF
:PRINT TAB(2) USINGF$(J%);X(J%);
:PRINT C$(J%,M)
:NEXT J%
390 IF PN=1 THEN PRINT@ 896,"> ";
:GOSUB 2160 ELSE PRINT@ 896,"< ";
:GOSUB 2160
400 NS=1
:CO=44
:GOSUB 2240
410     IF X<32 THEN 400
420     IF X$="*" THEN JS=1
: JF=21
: GOTO 490
430     IF X$="@" THEN GOSUB 2550
:GOTO 350
440     IF PN=1 AND X$=">" THEN PN=2
:P=1
:GOTO 350
450     IF PN=2 AND X$="<" THEN PN=1
:P=1
:GOTO 350
460 GOSUB 2210
:GOSUB 2380
470 X(P+(PN-1)*10)=Y
```

```
:P=P+1
:IF P)MX THEN P=1
480 GOTO 350
490 GOSUB 2100
:IF M=1 THEN GOSUB 2000
500 GOSUB 1730
510 PRINT"DOES PLANT HAVE AN FGD SYSTEM FOR SO2 CONTROL (Y OR N) ";
:GOSUB 2140
520 FI$=LEFT$(X$,1)
530 PRINT" FILING PLANT DATA"
540 PR%=1
:GOSUB 6150
550 GOSUB 2100
560 PRINT"NOW READY TO ENTER DEVICE INFORMATION"
570 PRINT"THE DEVICES ARE :";CHR$(10);TAB(28);"1. ESP"
580 PRINT TAB(28) "2. FABRIC FILTER";CHR$(10);TAB(28);"3. VENTURI SCRUBBER"
590 PRINT"ENTER 1,2, OR 3 FOR THE DEVICE YOU WANT TO COST ";
600 Y$=INKEY$
:IFY$="" THEN 600
610 PRINT Y$
620 IF INSTR("123",Y$)=0 THEN PRINT"PLEASE ANSWER 1,2, OR 3"
:GOTO600
630 I=VAL(Y$)
:ON I GOSUB 800,1440,1150
640 GOSUB 2100
650 PRINT"DO YOU WANT TO RUN ANOTHER CASE (Y OR N) ? ";
660 X$=""
:Y$=INKEY$
:IFY$="" THEN 660 ELSE PRINT Y$
: IF INSTR(A$,Y$)=0 THEN PRINT"ANSWER Y OR N PLEASE"
:GOTO660
670 IF Y$="N" THEN 710 ELSE PRINT"WITH THE SAME PLANT ? ";
680 GOSUB 2340
:PRINT X$
:IF INSTR(A$,X$)=0 THEN PRINT "ANSWER Y OR N PLEASE"
:GOTO 680
690 IF X$="Y" THEN GOTO 550
700 IF Y$="Y" THEN 190
710 CLS
720 PRINT CHR$(23)
:PRINT STRING$(30,"*")
730 PRINT"***********  DONE  ***********"
740 FOR I=1 TO 2
:PRINT STRING$(30,"*")
:NEXT I
750 PRINT"** REMOVE DISKS FROM DRIVES **"
760 PRINT"**********  BEFORE  **********"
770 PRINT"**** SHUTTING DOWN SYSTEM ****"
780 FOR I=1 TO 6
:PRINT STRING$(30,"*")
:NEXT I
790 END
```

```
800 GOSUB 2100
:LINE INPUT"       ESP NAME : ";NM$
810 IF LEN(NM$)>8 THEN NM$=LEFT$(NM$,8) ELSE NM$=NM$+"        "
:GOTO 810
820 FL=0
: GOSUB 6680
: IF FL=1 THEN RETURN
830 LINE INPUT"    REMARKS : ";CM$
:CM$=LEFT$(CM$,40)
840 PRINT
:PRINT"TYPE OF ESP : HOT OR COLD ? ";
:GOSUB 2340
:PRINT X$
850 IF INSTR("HC",X$)=0 THEN PRINT"ANSWER H OR C PLEASE "
:GOTO840
860 IF LEFT$(X$,1)="H" THEN X(22)=325
:ET=2 ELSE X(22)=150
:ET=1
870 PRINT
:PRINT"WILL THIS ESP BE FOLLOWED BY A VENTURI SCRUBBER ? ";
:GOSUB 2140
880 X$=LEFT$(X$,1)
:IF X$="Y" THEN A=3 ELSE A=1
890 JS=22
:JF=33
:PN=1
:NP=2
:P=1
:GOSUB 4010
: GOSUB 4190
:IF UN$="E" THEN GOSUB 2000
:X(22)=(X(22)+40)*(9/5)-40
900 CLS
:PRINT STRING$(63,"=")
:PRINT USING"ESP INPUT MODULE          PAGE ## OF ##";PN,NP
:PRINT STRING$(63,"=")
910 IF PN=1 THEN JS=22
:JF=27
:MX=6
920 IF PN=2 THEN JS=28
:JF=33
:MX=6
930 FOR J%=JS TO JF
:PRINT TAB(2)USING F$(J%);X(J%);
:PRINT C$(J%,M)
: NEXT J%
940 IF PN=1 THEN PRINT@ 896,"> "; ELSE PRINT@ 896,"< ";
950 GOSUB 2160
960 NS=1
:CO=44
:GOSUB2240
970    IF X<32 THEN 960
```

```
980      IF X$="*" THEN JS=22
: JF=33
: GOTO 1050
990      IF X$="@" THEN GOSUB 2550
:GOTO1040
1000 IF PN=1 AND X$=")" THEN PN=2
:P=1
:GOTO 900
1010 IF PN=2 AND X$="(" THEN PN=1
:P=1
:GOTO 900
1020      GOSUB 2210
:GOSUB 2380
1030 X(P+21+(PN-1)*6)=Y
:P=P+1
:IF P)MX THEN P=1
1040 GOTO 900
1050 NS=0
:IF M=1 THEN GOSUB 2000
:X(22)=(X(22)+40)*(5/9)-40
1060 AV=X(26)/100
:CD=X(24)
:GT=X(22)
:DP=X(27)
:LF=X(28)
:NF=X(29)
:HK= X(30)
:HF=X(31)
:RO=X(25)
:LP=X(23)
1070 AD=X(32)
:AR=X(33)
1080 IF GB=0 THEN 1100
1090 GC=GB*((GT+273)/273)*(PA-DP*10/13.6)/PA
1100 GOSUB 2120
1110 GOSUB 4800
:GOSUB4840
1120 GOSUB 5820
: GOSUB 6270
1130 IF A=3 THEN 1150
1140 RETURN
1150 GOSUB 2100
: LINE INPUT"      SCRUBBER NAME : ";NM$
: NM$=NM$+"        "
: NM$=LEFT$(NM$,8)
: FL=0
: GOSUB 7020
: IF FL=1 THEN RETURN
1160 LINE INPUT"      REMARKS : ";CM$
:CM$=LEFT$(CM$,40)
1170 P=1
:PN=1
```

```
:NP=2
:GOSUB 4210
:GOSUB 4400
:IF UN$="E" THEN JS=22
: JF=33
:GOSUB 2000
:X(22)=(X(22)+40)*(9/5)-40
1180 IF A<>3 THEN A=2
1190 CLS
:PRINT STRING$(63,"=")
:PRINT USING "VENTURI SCRUBBER COST INPUT                  PAGE ## OF ##";PN,NP
:PRINT STRING$(63,"=")
1200 IF PN=1 THEN JS=22
:JF=27
:MX=6
1210 IF PN=2 THEN JS=28
:JF=33
:MX=6
1220 FOR J%=JS TO JF
:PRINT TAB(2) USING F$(J%);X(J%);
:PRINT C$(J%,M)
:NEXT J%
1230 IF PN=1 THEN PRINT@ 896,">  "; ELSE PRINT@ 896,"< ";
1240 GOSUB 2160
1250 NS=1
:CO=44
:GOSUB2240
1260      IF X<32 THEN 1250
1270      IF X$="*" THEN JS=22
: JF=33
: GOTO 1340
1280      IF X$="@" THEN GOSUB 2550
:GOTO 1190
1290 IF PN=1 AND X$=">" THEN PN=2
:P=1
:GOTO 1190
1300 IF PN=2 AND X$="<" THEN PN=1
:P=1
:GOTO 1190
1310      GOSUB 2210
:GOSUB 2380
1320 X(P+21+(PN-1)*6)=Y
:P=P+1
:IF P>MX THEN P=1
1330 GOTO 1190
1340 NS=0
:IF M=1 THEN GOSUB 2000
:X(22)=(X(22)+40)*(5/9)-40
1350 GT=X(22)
:LP=X(23)
:LG=X(24)
:XP=X(25)
```

```
:QE=X(26)
:XE=X(27)/100
:XH= X(28)/100
:QF=X(31)
:QL=X(32)
:QM=X(33)
1360 RW=X(29)*215/CE
:RS=X(30)*215/CE
1370 IF GB=0 THEN 1390
1380 GC=GB*((GT+273)/273)*(PA-XP*10/13.6)/PA
1390 IF A=2 THEN GOSUB 4800
1400 GOSUB 2120
:GOSUB 5230
1410 GOSUB 5820
: GOSUB 6410
1420 A=0
1430 RETURN
1440 GOSUB 2100
: LINE INPUT"     BAGHOUSE NAME : ";NM$
:NM$=NM$+"        "
: NM$=LEFT$(NM$,8)
: FL=0
: GOSUB 6840
: IF FL=1 THEN RETURN
1450 LINE INPUT"     REMARKS : ";CM$
:CM$=LEFT$(CM$,40)
1460 P=1
:PN=1
:NP=2
:GOSUB 4430
:GOSUB 4700
:A=4
:IF UN$="E" THEN JS=22
:JF=42
: GOSUB 2000
:X(22)=(X(22)+40)*(9/5)-40
1470 CLS
:PRINT STRING$(63,"=")
:PRINT USING"FABRIC FILTER COST INPUT                  PAGE ## OF ##";PN,NP
:PRINT STRING$(63,"=")
1480 IF PN=1 THEN JS=22
:JF=31
:MX=10
1490 IF PN=2 THEN JS=32
:JF=42
:MX=11
1500 FOR J%=JS TO JF
:PRINT TAB(2) USING F$(J%);X(J%);
:PRINT C$(J%,M)
:NEXT J%
1510 IF PN=1 THEN PRINT@ 896,") "; ELSE PRINT@ 896,"( ";
1520 GOSUB 2160
```

```
1530 NS=1
:CO=46
:GOSUB2240
1540     IF X<32 THEN 1530
1550     IF X$="*" THEN JS=22
: JF=42
: GOTO 1620
1560     IF X$="@" THEN GOSUB 2550
: GOTO 1470
1570 IF PN=1 AND X$=")" THEN PN=2
:P=1
:GOTO 1470
1580 IF PN=2 AND X$="(" THEN PN=1
:P=1
:GOTO 1470
1590     GOSUB 2210
:GOSUB 2380
1600 X(P+21+(PN-1)*10)=Y
:P=P+1
: IF P>MX THEN P=1
1610 GOTO 1470
1620 NS=0
:IF M=1 THEN GOSUB 2000
: X(22)=(X(22)+40)*(5/9)-40
1630 GT=X(22)
:LP=X(23)
:V=X(24)
:XP=X(25)
:DP=X(26)
:MD=X(27)
:AF=X(28)
1640 BL=X(29)
:BE=X(30)
:UF=X(41)
:NB=X(42)
:LF=X(34)
1650 BC=X(31)*215/CE
:LR=X(32)*215/CE
1660 NF=X(35)/100
:MO=X(33)
1670 HF=X(36)
:AD=X(37)
:AR=X(38)
:BS=X(39)
:UB=X(40)
1680 IF GB=0 THEN 1700
1690 GC=GB*((GT+273)/273)*(PA-DP*10/13.6)/PA
1700 GOSUB 2120
: GOSUB 5550
1710 GOSUB 5820
: GOSUB 6550
1720 RETURN
```

```
1730 '***       VARIABLE INITIALIZATION         ***
1740 IF INT(X(12))>0 THEN PB=X(12)
: GOTO 1760
1750 PB=0.8*X(20)*1E7/X(13)
1760 EP=X(4)/PB
1770 SZ=X(1)
:CF=X(2)/100
:CE=X(3)
:PL=X(4)
:PA=760-.026*X(5)*3.281
:IR=X(6)
:CK=X(7)/1000
:MC=X(8)/100
1780 XR=IR/100
:CI=CE/215
1790 EF=X(9)/100
:TE=X(10)
:HV=X(13)
:C1=X(15)
:H1=X(16)
:O2=X(17)
1800 S2=X(18)
:N2=X(19)
:FA=X(20)/100
:W=X(21)
:EA=X(14)
1810 GB=0
: IF INT(X(11))>0 THEN GC=X(11)
:GOTO 1850
1820 FR=1E5/0.454*1.0/X(10)*X(1)/X(13)
1830 GB=17.10*(X(15)/12+X(16)/4-X(17)/32+X(18)/32)*(1+X(14))*760/(
760-0.026*X(5)*3.281)
1840 GB=GB*FR*(0.3048)[3
1850 HR=3.6E5/X(10)
:AQ=(1-EP)*PB*HR*SZ/1.0E6
:GOSUB 5770
:RETURN
1860 '
1870 OPEN"R",1,F$
1880 FIELD 1,2 AS Z$(1),2 AS Z$(2),2 AS Z$(3),4 AS Z$(4),2 AS Z$(5),4 AS Z$(6)
1890 FIELD 1,16 AS DUM$,2 AS Z$(7),2 AS Z$(8),2 AS Z$(9),2 AS Z$(10),2 AS
Z$(11),4 AS Z$(12)
1900 FIELD 1, 30 AS DUM$,2 AS Z$(13),2 AS Z$(14),2 AS Z$(15),2 AS Z$(16)
1910 FIELD 1, 38 AS DUM$,2 AS Z$(17),2 AS Z$(18),2 AS Z$(19),2 AS Z$(20)
1920 FIELD 1, 46 AS DUM$,2 AS Z$(21),1 AS FG$,70 AS RM$,8 AS DT$,8 AS Z$
1930 FIELD 1,247 AS DUM$,2 AS CC$,2 AS FO$,2 AS VO$, 2 AS EC$
1940 GET 1,1
: PR%=LOF(1)+1
: CLOSE 1
1950 X(1)=CVI(Z$(1))
:X(2)=CVI(Z$(2))/10.0
:X(3)=CVI(Z$(3))/10.0
```

```
:X(4)=CVS(Z$(4))
:X(5)=CVI(Z$(5))
:X(6)=CVS(Z$(6))
1960 FOR I%=7 TO 10
:X(I%)=CVI(Z$(I%))/100.0
:NEXT I%
1970 X(13)=CVI(Z$(13))
:FOR I%=14 TO 21
:X(I%)=CVI(Z$(I%))/100.0
:NEXT I%
1980 X(11)=CVI(Z$(11))
:X(12)=CVS(Z$(12))
1990 RETURN
2000 REM THIS IS THE UNITS CONVERSION ROUTINE
2010 FOR J%=JS TO JF
:X(J%)=X(J%)*C(J%)
:C(J%)=1/C(J%)
:NEXT J%
2020 IF CN=1 THEN M=0
2030 IF CN=0 THEN M=1
: CN=1
:RETURN
2040 CN=0
2050 RETURN
2060 PRINT
:PRINT STRING$(63,"=")
2070 PRINT"                 PARTICULATE COST MODEL PROGRAM
                          VERSION 1.1
                 BY A. S. VINER & L. E. SPARKS"
2080 PRINT
:PRINT"                1 JUNE 1981 EPA CONTRACT # 68-02-3146"
2090 PRINT STRING$(63,"=")
:RETURN
2100 ' DISPLAY PLANT NAME ON SCREEN
2110 CLS
:PRINT STRING$(63,"=")
:PRINT "PLANT
: ";P$
:PRINT STRING$(63,"=")
:RETURN
2120 ' THINKING
2130 CLS
:FOR I=1 TO 6
:PRINT" "
:NEXT
:PRINT CHR$(23)
:PRINTTAB(8) "THINKING"
: RETURN
2140 ' YES/NO INPUT
2150 GOSUB 2340
:PRINT X$
: IF INSTR(A$,X$)=0 THEN PRINT"PLEASE ANSWER Y OR N "
```

```
:GOTO 2150 ELSE RETURN
2160 REM *** MENU INSTRUCTIONS ***
2170 PRINT "MAY BE USED TO CHANGE PAGES.  ";
2180 PRINT "UP AND DOWN ARROWS ARE ACTIVE"
2190 PRINT "USE '*' TO INITIATE COMPUTATION.";
2200 PRINT "  ENTER DATA TO CHANGE";
: RETURN
2210 PRINT @896,"USE ";CHR$(93);" FOR CORRECTIONS";CHR$(30)
2220 PRINT "ENTER REST OF ITEM AND <ENTER> TO CHANGE";CHR$(30);
2230 RETURN
2240 REM *** POINTER CONTROL FOR MENUES ***
2250 PRINT @P*64+CO+126,CHR$(45);CHR$(45);CHR$(62);
2260 GOSUB 2340
2270 PRINT @P*64+CO+126,"   ";
2280 DD=0
2290 IF X=27 OR X=91 THEN DD=-1
2300 IF X=26 OR X=10 OR X=13 THEN DD=+1
2310 P=P+DD
: IF P<1 THEN P=MX
2320 IF P>MX THEN P=1
2330 IF DD=0 THEN RETURN ELSE 2240
2340 REM *** GET AN UNSHIFTED CHARACTER FROM KEYBOARD ***
2350 X$=INKEY$
: IF X$="" THEN 2350 ELSE X=ASC(X$)
2360 IF X>95 THEN X=X-32
: X$=CHR$(X)
2370 RETURN
2380 REM *** NUMERIC PARAMETER INPUT USING SUBR @ 1900
2390 PRINT @P*64+CO+128,STRING$(7," ");
2400 GOSUB 2450
:I%=INSTR(Y$,"%")
:IF I%=0 THEN 2410 ELSE Y$=LEFT$(Y$,I%-1)
:GOTO2430
2410 I%=INSTR(Y$,",")
:IF I%=0 THEN 2430 ELSE Y$=LEFT$(Y$,I%-1)+RIGHT$(Y$,LEN(Y$)-I%)
2420 GOTO 2410
2430 Y=VAL(Y$)
2440 RETURN
2450 REM *** STRING INPUT, ADDING TO Y$ STARTING WITH X$ ***
2460 CO=CO+1
2470 Y$=X$
2480 PRINT @P*64+CO+128,Y$;CHR$(95);" ";
2490 GOSUB 2340
2500   IF X=13 THEN RETURN
2510   IF X=8 THEN IF LEN(Y$)>0 THEN Y$=LEFT$(Y$,LEN(Y$)-1)
2520   IF X=24 THEN Y$=""
2530   IF X>31 THEN Y$=Y$+X$
2540 GOTO 2480
2550 REM INSTRUCTION SUBROUTINE
2560 CLS
2570 PRINT STRING$(63,"=")
2580 PRINT"              *****  INSTRUCTIONS FOR COST PROGRAMS  *****"
```

```
2590 PRINT STRING$(63,"=")
2600 PRINT"      THESE PROGRAMS PROVIDE ESTIMATES OF THE CAPITAL AND OPER-"
2610 PRINT"ATING COSTS FOR PARTICULATE CONTROL DEVICES FOR COAL FIRED "
2620 PRINT"BOILERS.  THE DEVICES COVERED ARE REVERSE AIR AND SHAKE "
2630 PRINT"FABRIC FILTERS, HOT AND COLD SIDE ELECTROSTATIC PRECIPITATORS,"
2640 PRINT"AND VENTURI SCRUBBERS EITHER ALONE OR IN SERIES WITH AN ESP."
2650 PRINT
2660 PRINT"   IN ORDER TO USE THE PROGRAMS, YOU MUST PROVIDE THE COMPUTER"
2670 PRINT"WITH INFORMATION ON THE PLANT AND THE CONTROL DEVICE. THIS"
2680 PRINT"INFORMATION IS ENTERED INTO THE COMPUTER BY FILLING OUT"
2690 PRINT"THE INFORMATION FORMS SHOWN ON THE TV SCREEN."
2700 PRINT
:PRINT"PRESS ANY KEY TO CONTINUE "
2710 Y$=INKEY$
:IFY$="" THEN 2710 ELSE CLS
2720 PRINT STRING$(64,"=")
2730 PRINT"THE FIRST BLOCK OF INFORMATION THAT IS REQUIRED IS SPECIFIC "
2740 PRINT"TO THE PLANT BEING STUDIED. THESE DATA INCLUDE PLANT NAME,"
2750 PRINT"PLANT GENERATING CAPACITY, NET, COAL ANALYSIS ETC. THE "
2760 PRINT"INFORMATION REQUIRED IS ASKED FOR BY NAME, SO YOU SHOULD "
2770 PRINT"NOT HAVE ANY TROUBLE IN FILLING OUT THE FORM."
2780 PRINT"NOTE THAT SOME OF THE ITEMS HAVE DEFAULT VALUES. IF YOU"
2790 PRINT"WISH TO USE THE DEFAULT PRESS ENTER OR THE ";CHR$(92);" KEY TO MOVE
TO"
2800 PRINT"THE NEXT ITEM ON THE LIST. USE THE ";CHR$(91);" KEY TO MOVE UP THE
LIST."
2810 PRINT"THE PLANT FORM HAS TWO PAGES. WHEN YOU HAVE FILLED OUT THE"
2820 PRINT"FIRST PAGE AND ARE SURE THE DATA ARE CORRECT, PRESS THE "
2830 PRINT"> KEY TO MOVE TO PAGE 2. FILL OUT PAGE 2. IF YOU WISH TO"
2840 PRINT"MOVE BACK TO PAGE 1, PRESS THE < KEY."
2850 PRINT
:PRINT"PRESS ANY KEY TO CONTINUE"
2860 Y$=INKEY$
:IFY$="" THEN 2860 ELSE CLS
2870 PRINT"WHEN ALL OF THE PLANT DATA HAVE BEEN ENTERED AND WHEN YOU"
2880 PRINT"ARE SURE THAT THEY ARE CORRECT, PRESS THE * KEY. AS SOON"
2890 PRINT"AS THE * IS PRESSED, THE COMPUTER WILL FILE THE DATA ON DISK"
2900 PRINT"AND THEN ASK FOR DEVICE SPECIFIC INFORMATION. THE DEVICE"
2910 PRINT"INFORMATION IS PROVIDED BY FILLING OUT FORMS IN THE SAME"
2920 PRINT"MANNER AS WAS USED TO PROVIDE THE PLANT DATA. AFTER"
2930 PRINT"THE DEVICE INFORMATION HAVE BEEN ENTERED, PRESS * TO"
2940 PRINT"BEGIN CALCULATIONS. THE COMPUTER WILL CALCULATE THE CAPITAL"
2950 PRINT"AND OPERATING COSTS FOR THE DEVICE YOU SPECIFIED. IF YOU"
2960 PRINT"WISH, THE COST DATA CAN BE STORED ON DISK."
2970 PRINT"WHEN THE COST CALCUALTIONS ARE COMPLETED, YOU WILL BE ASKED"
2980 PRINT"IF YOU WANT TO RUN ANOTHER CASE. IF YOU DO, YOU WILL BE"
2990 PRINT"TRANSFERED BACK TO THE PLANT INPUT SECTION."
3000 PRINT"PRESS ANY KEY TO CONTINUE."
3010 Y$=INKEY$
:IFY$="" THEN 3010 ELSE CLS
3020 PRINT STRING$(64,"=")
3030 PRINT"IF THE PLANT IS THE SAME AS A PREVIOUS PLANT, THE COMPUTER"
```

```
3040 PRINT"WILL RETRIEVE THE DATA FROM DISK AND USE THAT DATA TO FILL"
3050 PRINT"IN THE FORM."
3060 PRINT
3070 PRINT"IF YOU NEED HELP WHILE YOU ARE FILLING IN THE FORMS, "
3080 PRINT"PRESS THE @ KEY AND YOU WILL BE TRANSFERED TO THIS PORTION"
3090 PRINT"OF THE PROGRAM."
3100 PRINT STRING$(63,"=")
3110 PRINT"PRESS ANY KEY TO RETURN"
3120 Y$=INKEY$
:IF Y$="" THEN 3120 ELSE CLS
:RETURN
3130 '
3140 ' PLANT DATA INITIALIZATION
3150 '
3160 F$(1)="BOILER SIZE                                    ##### MW NET"
3170 F$(2)="CAPACITY FACTOR                                 ##.# %"
3180 F$(3)="CHEM. ENG. PLANT COST INDEX                     ####.#"
3190 F$(4)="EMISSION LIMIT                               #####.# "
3200 F$(5)="PLANT ALTITUDE                                   #### "
3210 F$(6)="INTEREST RATE                                   ##.## %/YR"
3220 F$(7)="COST OF ELECTRICITY                              ##.## MIL/KWH"
3230 F$(8)="CONTINGENCY AS PERCENT OF FIELD COST            ##.# %"
3240 F$(9)="ENGINEERING AS PERCENT OF FIELD COST            ##.# %"
3250 F$(10)="STEAM CYCLE EFFICIENCY                           ##.# %"
3260 F$(11)="GAS FLOW RATE                                  #,### "
3270 F$(12)="BOILER EMISSIONS                               ###.# "
3280 F$(13)="COAL HEATING VALUE                            ####,# "
3290 F$(14)="FRACTION EXCESS AIR                             #.##"
3300 F$(15)="PERCENT CARBON IN COAL                         ##.## %"
3310 F$(16)="PERCENT HYDROGEN IN COAL                       ##.## %"
3320 F$(17)="PERCENT OXYGEN IN COAL                         ##.## %"
3330 F$(18)="PERCENT SULFUR IN COAL                         ##.## %"
3340 F$(19)="PERCENT NITROGEN IN COAL                       ##.## %"
3350 F$(20)="PERCENT ASH IN COAL                            ##.## %"
3360 F$(21)="PERCENT WATER IN COAL                          ##.## %"
3370 FOR I=1 TO 21
:C(I)=1
:NEXT I
:C(4)=2.326E-3
:C(5)=3.281
:C(13)=0.43
:C(11)=2.1189
:C(12)=2.326E-3
3380 FOR I=0 TO 1
:FOR J=1 TO 21
:C$(J,I)=""
:NEXT J
:NEXT I
3390 C$(4,0)="NG/J"
:C$(5,0)="M"
:C$(11,0)="ACMS"
:C$(12,0)="NG/J"
```

```
:C$(13,0)="KJ/KG"
:C$(4,1)="LB/MBTU"
:C$(5,1)="FT"
:C$(11,1)="KACFM"
:C$(12,1)="LB/MBTU"
:C$(13,1)="BTU/LB"
:RETURN
3400 X(1)=500
:X(2)=70
:X(3)=270
:X(4)=43
:X(5)=300
3410 X(6)=15
:X(7)=30
:X(8)=20
:X(9)=20
3420 X(10)=38
:X(20)=7.6
:X(21)=13.6
:X(13)= 23240
3430 X(15)=60
:X(16)=5.4
:X(17)=11.2
:X(18)=.6
:X(19)=1.6
:X(14)=0.25
:RETURN
3440 R$(1)="COLLECTOR & SUPPORTS                    $##.##[[[[##"
3450 R$(2)="DUCTING & SUPPORTS                      $##.##[[[[##"
3460 R$(3)="ASH REMOVAL SYSTEM                      $##.##[[[[##"
3470 R$(4)="INSULATION                              $##.##[[[[##"
3480 R$(5)="ASH POND                                $##.##[[[[##"
3490 R$(6)="ID FAN                                  $##.##[[[[##"
3495 R$(7)="MISCELLANEOUS                           $##.##[[[[##"
3500 R$(8)="TOTAL FIELD COST....................................$##.##[[[[##"
3510 R$(9)="ENGINEERING                             $##.##[[[[##"
3520 R$(10)="CONTINGENCY                             $##.##[[[[##"
3530 R$(11)="TURN-KEY COST.......................................$##.##[[[[##"
3540 R$(12)="FIXED OPERATING COSTS                   $##.##[[[[##"
3550 R$(13)="VARIABLE OPERATING COSTS                $##.##[[[[##"
3560 R$(14)="COST OF ELECTRICITY                     $##.##[[[[##"
3570 R$(15)="ANNUAL CAPITAL COST.................................$##.##[[[[##"
3580 R$(16)="TOTAL ANNUAL COST...................................$##.##[[[[##"
4000 RETURN
4010 ' ESP DATA INITIALIZATION
4020 '
4030 F$(22)="GAS TEMPERATURE                                 ### "
4040 F$(23)="EXPECTED ESP LIFE                                ## YRS"
4050 F$(24)="CURRENT DENSITY                               ##.## NA/CM[2"
4060 F$(25)="FLYASH RESISTIVITY                         ##.#[[[[##"
4070 F$(26)="SPECIFIC COLLECTION AREA                    ####.## "
4080 F$(27)="ESP PRESSURE DROP                              ###.## "
```

```
4090 F$(28)="FAN LOAD FACTOR (0<>1)                         #.##"
4100 F$(29)="FAN EFFICIENCY                                ##.## %"
4110 F$(30)="HOPPER HEATER POWER                           ##.## KW/HOPPER"
4120 F$(31)="HOPPER HEATER DUTY FACTOR (0<>1)               #.##"
4130 F$(32)="ACCESORIES DUTY FACTOR (0<>1)                  #.##"
4140 F$(33)="ASH REMOVAL SYSTEM DUTY FACTOR (0<>1)          #.##"
4150 FOR I=0 TO 1
:FOR J=22 TO 33
:C$(J,I)=""
:NEXT J
:NEXT I
4160 FOR I%=22 TO 33
:C(I%)=1
:NEXT I%
:C(26)=5.08
:C(27)=0.3937
4170 C$(26,0)="M[2/M[3/S"
:C$(26,1)="FT2/KACFM"
:C$(27,0)="CM H20"
:C$(27,1)="IN. H20"
4180 C$(25,0)=" OHM CM"
:C$(25,1)=" OHM CM"
:C$(22,0)=" C"
:C$(22,1)=" F"
:RETURN
4190 X(28)=.82
:X(29)=80
:X(30)=10
:X(31)=.3
:X(32)=.8
:X(33)=.6
:X(25)=2.0E10
:X(23)=20
4200 X(24)=20
:X(27)=7.5
:X(26)=55
:RETURN
4210 '
4220 ' VENTURI SCRUBBER DATA INITIALIZATION
4230 '
4240 F$(22)="GAS TEMPERATURE                                   ###"
4250 F$(23)="EXPECTED SCRUBBER LIFE                             ## YRS"
4260 F$(24)="L/G                                           ##.##[[[[##"
4270 F$(25)="PRESSURE DROP                                   ##.##"
4280 F$(26)="NUMBER OF SPARE MODULES                            ##"
4290 F$(27)="FAN EFFICIENCY                                   ##.# %"
4300 F$(28)="HOLDING TANK PUMP EFFICIENCY                     ##.# %"
4310 F$(29)="WATER COST                                    $ ##.##"
4320 F$(30)="STEAM COST                                    $ ##.##"
4330 F$(31)="EQUIPMENT COST FRACTION                         #.###"
4340 F$(32)="LABOR COST FRACTION                             #.###"
4350 F$(33)="MAINTENANCE COST FRACTION                       #.###"
```

```
4360 FOR I=22 TO 33
:C(I)=1
:NEXT I
:FOR I=0 TO 1
:FOR J=22 TO 33
:C$(J,I)=""
:NEXT J
:NEXT I
4370 C$(25,0)=" CM H20"
:C$(25,1)=" IN. H20"
:C$(29,0)=" /M3"
:C$(29,1)=" /FT3"
4380 C$(30,0)=" /GJ"
:C$(30,1)=" /MBTU"
:C$(22,0)=" C"
:C$(22,1)=" F"
4390 C(25)=0.3937
:C(29)=1/(0.3048)[3
:C(30)=1.0548
:RETURN
4400 X(22)=150
:X(23)=12
:X(24)=1.34E-3
:X(25)=38
:X(26)=1
:X(27)=80.0
:X(28)=80.0
:X(29)=0.05
:X(30)=2.7
4410 X(31)=0.639
:X(32)=.82
:X(33)=0.015
4420 RETURN
4430 '
4440 ' FABRIC FILTER DATA INITIALIZATION
4450 '
4460 F$(22)="GAS TEMPERATURE                                   ###"
4470 F$(23)="EXPECTED BAGHOUSE LIFE                             ## YRS"
4480 F$(24)="AIR TO CLOTH RATIO                              #.###"
4490 F$(25)="MAXIMUM PRESSURE DROP                           ##.##"
4500 F$(26)="AVERAGE PRESSURE DROP                           ##.##"
4510 F$(27)="NUMBER OF MODULES                                  ##"
4520 F$(28)="REVERSE AIR FAN SIZE (KW/10[5 M2 BAG AREA)        ###"
4530 F$(29)="BAG LIFE                                         ##.# YEARS"
4540 F$(30)="BAG LIFE EXPONENT                               #.###"
4550 F$(31)="BAG REPLACEMENT COST                          $ ##.##"
4560 F$(32)="LABOR RATE                                    $ ##.## /HR"
4570 F$(33)="MATERIAL OVERHEAD FRACTION                      #.###"
4580 F$(34)="FAN LOAD FACTOR                                 #.###"
4590 F$(35)="FAN EFFICIENCY                                  ###.# %"
4600 F$(36)="HOPPER HEATER DUTY FACTOR                       #.###"
4610 F$(37)="ACCESORIES DUTY FACTOR                          #.###"
```

```
4620 F$(38)="ASH REMOVAL SYSTEM DUTY FACTOR                 #.###"
4630 F$(39)="SCHEDULED BAG REPLACEMENT TIME                    ## MIN/M2"
4640 F$(40)="UNSCHEDULED BAG REPLACEMENT TIME                  ## MIN/M2"
4650 F$(41)="FRACTION OF UNSCHEDULED BAG REPLACEMENTS       #.###"
4660 F$(42)="NON BAG MAINTENANCE TIME (HR/YR/1000 CMS)        ###"
4670 FOR I=22 TO 42
:C(I)=1
:NEXT I
:FOR I=0 TO 1
:FOR J=22 TO 42
:C$(J,I)=""
:NEXTJ
:NEXT I
4680 C$(22,0)=" C"
:C$(22,1)=" F"
:C$(24,0)=" M/MIN"
:C$(24,1)=" FT/MIN"
:C$(25,0)=" CM H2O"
:C$(25,1)=" IN H2O"
:C$(26,0)=" CM H2O"
:C$(26,1)=" IN H2O"
4690 C$(31,0)=" /M2"
:C$(31,1)=" /FT2"
:C(24)=3.28
:C(25)=.3937
:C(26)=0.3937
:C(31)=.0929
:RETURN
4700 X(22)=150
:X(23)=20
:X(24)=0.632
:X(25)=40
:X(26)=30
:X(27)=16
4710 X(28)=240
:X(29)=2
:X(30)=0.60
:X(31)=7
:X(41)=0.05
:X(42)=560
4720 X(34)=0.82
:X(35)=80.0
:X(32)=14
:X(33)=0.10
4730 X(36)=0.3
:X(37)=0.8
:X(38)=0.6
:X(39)=2
:X(40)=7
4740 RETURN
4750 '
4760 ' ANNUALIZED, LEVELLIZED COST
```

```
4770 '
4780 LP=X(23)
:C6=(XR*(1+XR)[LP)/((1+XR)[LP-1)
:A1=C6*CC
:LV=A1+VO+EC+FO
:PRINT USING R$(15);A1
4790 PRINT USING R$(16);LV
:RETURN
:END
4800 '
4810 ' ZERO OUT COST VALUES
4820 '
4830 CC=0.0
:FO=0.0
:VO=0.0
:EC=0.0
:CP=0.0
:RETURN
:END
4840 '
4850 ' MAIN ESP COST SUBROUTINE
4860 '
4870 EO=2.0E4
:AO=6.0E4
:PC=0.0
:IFA<>1GOTO4890
4880 PC=PF*CE/148.2
4890 AE=AV*GC*100.0
:TA=AE*1.0E4*CD*1.0E-9
:TK=TA*30.0
:TW=TK*8760.0/0.6
4900  IF ET = 1 GOSUB4970
4910 IFET=2GOSUB5100
4920 CLS
: PRINT TAB(24)"ESP COST SUMMARY"
4930 PRINT TAB(15) USING"COLLECTOR AREA = ####,# SQ METERS";AE
:PRINT STRING$(63,"*")
4940 PRINT USING R$(1);ED
:PRINT USING R$(2);DC
:PRINT USING R$(3);AC
:PRINT USING R$(4);IC
:PRINT USING R$(5);PC
:PRINT USING R$(6);CB
:PRINT USING R$(7);M6
4950 PRINT USING R$(8);FD
:PRINT USING R$(9);EN
:PRINT USING R$(10);CA
:PRINT USING R$(11);CC
4955 PRINT" "
:PRINT"PRESS ANY KEY TO CONTINUE";
:GOSUB 2340
4960 CLS
```

```
:PRINT TAB(24)"ESP COST SUMMARY"
:PRINT TAB(19) USING"CAPACITY PENALTY = ##.## %";CP*100
:PRINT STRING$(63,"*")
4962 PRINT USING R$(11);CC
:PRINT USING R$(12);FO
:PRINT USING R$(13);VO
: PRINT USING R$(14);EC
:PRINT" "
:GOSUB 4750
:RETURN
4970 '
4980 ' COST SUBROUTINE FOR COLDSIDE ESP
4990 '
5000 SF=AV/0.68898
:GF=GC/929.74
:IFGC>350.0THEN5020
5010 FD=PC+CI*10814020.0*SF[.6*GF[.737
:GOTO5050
5020 ED=CI*4.724E6*SF[.94*GF[.97
:DC=CI*3.134E6*GF[.83
:AC=CI*7.03E5*SF[.72*GF[.78
:IC=CI*9.43E5*SF[.34*GF[.97
5030 HP=GC*DP/7.618
:CB=80.0*HP*CE/148.2
5040 M6=CI*3.554E6*SF[.74*GF[1.02
:FD=ED+DC+AC+IC+M6+PC+CB
:ZC=ED
5050 ZC=ED
:EN=FD*EF
:CA=FD*MC
:EM=AE*.769
:PM=.015*PC*1.5/.65
:AM=.308*AE
:NH=AE/1335
:KH=NH*HK*8760*HF
5060 AK=AE*3229E-6*8760*AD
:KA=AE*7788E-6*8760*AR
5070 FK=8760*HP*.746*LF/NF
:EK=TW+KH+AK+KA+FK
:FO=(EO+AO)*CE/215
:VO=CF*(EM+AM+PM)*CE/215
5080 EC=EK*CK*CF
:CC=FD+EN+CA
5090 CP=EK/(SZ*8760*1000)
:RETURN
:END
:END
5100 '
5110 ' COST SUBROUTINE FOR HOTSIDE ESP
5120 '
5130 SF=AV/.7874
:GF=GC/1245.94
```

```
:IFGC>472THEN5150
5140 FD=CI*17.424E6*SF[.58*GF[.77
:GOTO5180
5150 ED=CI*7.235E6*SF[.935*GF[.968
:DC=CI*3.705E6*GF[.939
:AC=CI*5.82E5*SF[.76*GF[.748
5160 CS=GC*(150+273.15)/(GT+273.15)
:HP=CS*DP/7.618
:CB=80.0*HP*CE/148.2
5170 IC=CI*1.523E6*SF[.468*GF[.874
:M6=CI*8.114E6*SF[.526*GF[1.049
:FD=ED+DC+AC+IC+M6+PC+CB
5180 ZC=ED
:EN=FD*EF
:CA=FD*MC
:EM=.769*AE
:PM=.015*PC*1.5/.65
:AM=.923*AE
:AK=AE*3229E-6*8760*AD
5190 KA=AE*5.097E-3*8760*AR
5200 FK=8760*HP*.746*LF/NF
:EK=TW+AK+KA+FK
:FO=(EO+AO)*CE/215
:VO=CF*(EM+PM+AM)*CE/215
5210 EC=EK*CK*CF
:CC=FD+EN+CA
5220 CP=EK/(SZ*8760*1000)
:RETURN
:END
:END
5230 '
5240 'VENTURI SCRUBBER COSTING SUBROUTINE
5250 '
5260 CG=.83*GC
:MD=CG/175.
:IFMD<>FIX(MD)THENMD=FIX(MD+1)
5270 M5=CG/MD
:IFFI$="Y"ANDMD>1THENMD=MD+QE
5280 C5=1.35*M5[(-.138)+6.1753E-5*XP*M5[1.242
:C8=1590.*C5*M5
:C9=MD*C8
:IFCG<=175.THENDC=1011.*SQR(M5)
5290 IFCG>175.ANDCG<=350.THENDC=1695.*SQR(M5)
5300 IFCG>350.THENDC=2577.*M5[.46
5310 DC=DC*MD
:VC=278.*M5*MD
:TS=300.*LG*M5
:TC=MD*809.*TS[.643
:GD=MD*2000.*TS/100.
5320 HO=LG*M5
:NP=HO/.631
:IF NP<>FIX(NP)THENNP=FIX(NP+1)
```

```
5330 PG=HO/NP
:NP=NP+1
:PD=MD*NP*19607.*PG[.457
:HX=MD*M5*636.
:SB=MD*1475.*M5[.696
5340 MH=M5*(273+79.4)/(273+51.7)
:FH=MD*MH*XP/7.618
:FE=80*FH
:IFFI$<>"Y"GOTO 5380
5350 IFAQ<=26670.THENCR=146.5*AQ[.63
5360 IFAQ>26670.THENCR=333.7*AQ[.63
5370 GOTO5420
5380 IFAQ<=45360.THENCR=1554.*AQ[.47
5390 IFAQ>45360.ANDAQ<=90720.THENCR=2338.*AQ[.47
5400 IFAQ>90720.ANDAQ<=136080.THENCR=2783.*AQ[.47
5410 IFAQ>136080THENCR=3308.*AQ[.47
5420 EQ=C9+TC+GD+PD+FE+CR
:IFFI$<>"Y"THENEQ=EQ+HX+SB+DC+VC
5430 DR=EQ*(1+QF+QL)
:IN=.395*(DR+PC)+.1*DR
:CA=MC*(DR+IN+PC)
5440 C3=DR+IN+CA+PC
:CQ=C3*CE/148.2
:LS=8E4
:MT=QM*CQ*1.5/.65
:RX=LG*CG*3600*8760*RW
5450 HT=CG*.1341
:RI=HT*RS*8760
:CH=1.32E-2*AQ
:PH=400*LG*CG/XH
5460 FH=FH/XE
:TH=CH+PH+FH
:EJ=TH*.7457*8760.
:VE=CF*(EJ*CK)*CE/215.
:VF=LS*CE/215.
:VV=MT+(RX*CE/215.)
:IFFI$<>"Y"THENVV=MT+((RX+RI)*CE/215.)
5470 VV=VV*CF
:CLS
:VP=EJ/(SZ*8760.*1000.)
:IFFI$="Y"THENHT=0.0
5480 ER=HT*1E9/(SZ*1E3*HR*1E3)+VP
:CC=CC+CQ
:FO=FO+VF
:VO=VO+VV
:EC=EC+VE
:CP=CP+VP
:PRINT"COSTS FOR VENTURI SCRUBBER WITH ";XP;" CM H2O PRESSURE DROP"
:PRINTTAB(20)"(IN MILLIONS OF DOLLARS)"
:PRINT
5490 PRINT"CAPITAL COST",,CQ*1E-6
:PRINT"FIXED OP",,VF*1E-6
```

```
:PRINT"VARIABLE OP",,VV*1E-6
:PRINT"COST OF ELECTRICITY",VE*1E-6
:PRINT"CAPACITY PENALTY",VP
:PRINT"ENERGY PENALTY",,ER
:PRINT"
5500 PRINT"PRESS ANY KEY TO CONTINUE"
:GOSUB 2340
:CLS
5510 PRINT"    "
:PRINT"  "
:IFA=3PRINT"COSTS FOR COMBINATION ESP-VEN SYSTEM (MILLIONS OF DOLLARS)
5520 PRINT"  "
:IFA()3GOTO5540
5530 PRINT"CAPITAL COST",,CC*1E-6
:PRINT"FIXED OP",,FO*1E-6
:PRINT"VARIABLE OP",,VO*1E-6
:PRINT"COST OF ELECTRICITY",EC*1E-6
:PRINT"CAPACITY PENALTY",CP
:PRINT"ENERGY PENALTY",,ER
5540 GOSUB4750
:RETURN
:END
:END
5550 '
5560 ' FABRIC FILTER COST SUBROUTINE
5570 '
5580 AO=6E4
:OC=2.E4
:A8=V/.55
:GF=GC/929.74
:MF=MD/16.
:FF=CI*5.914E6*A8[(-.68)*GF[.72*MF[.21
5590 DC=CI*8.27E5*GF[.72
:AC=CI*5.53E5*GF[.49*MF[.62
5600 IC=CI*1.55E6*A8[(-.53)*GF[.61*MF[.31
:M6=CI*4.068E6*A8[(-.54)*GF[.79*MF[.18
5610 PC=PF*CE/148.2
:HP=GC*XP/7.618
:CB=80.*HP*CE/148.2
5620 FD=FF+DC+AC+IC+M6+PC+CB
:EN=FD*EF
:ZC=FF
5630 CA=FD*MC
5640 CC=FD+EN+CA
:BA=GC*60./V
:LB=BL/(V/.61)[BE
5650 X4=BA*BC/LB*(1.0+MO)
:X5=BA*BS/60.0*LR/LB
:X7=BA*BC*(1.0+MO)*UF
5660 X8=BA*UF*LR*UB/60.
:BM=(X4+X5+X7+X8)/.70
:ML=GC*NB*LR/1000.
```

```
:OM=2*ML
:AM=25.5*GC*MF
5670 PM=0.015*PC*1.5/.65
:HP=GC*DP/7.618
:FK=8760.*HP*.746*LF/NF
:KH=MD*15*8760.*HF
5680 RK=AF*BA/1E5
:RH=RK*8760.
:AK=2153.E-6*BA*AD*8760.
:KA=0.557*GC*8760.*AR
5690 FJ=FK+KH+RH+AK+KA
:FO=(OC+AO)*CE/215.
:VO=CF*(BM+OM+AM+PM)*CE/215.
:EC=FJ*CK*CF
:CP=FJ/(SZ*8760.*1000.)
5700 CLS
: PRINTTAB(19)"FABRIC FILTER COST SUMMARY"
:PRINT TAB(18) USING"FACE VELOCITY = ##.## M/MIN";V
:PRINT STRING$(63,"*")
5710 PRINT USING R$(1);FF
:PRINT USING R$(2);DC
:PRINT USING R$(3);AC
:PRINT USING R$(4);IC
:PRINT USING R$(5);PC
:PRINT USING R$(6);CB
:PRINT USING R$(7);M6
5720 PRINT USING R$(8);FD
:PRINT USING R$(9);EN
:PRINT USING R$(10);CA
:PRINT USING R$(11);CC
5722 PRINT" "
:PRINT"PRESS ANY KEY TO CONTINUE";
:GOSUB 2340
5724 CLS
:PRINT TAB(19)"FABRIC FILTER COST SUMMARY"
:PRINT TAB(19) USING"CAPACITY PENALTY = ##.## %";CP*100
:PRINT STRING$(63,"*")
5726 PRINT USING R$(11);CC
:PRINT USING R$(12);FO
:PRINT USING R$(13);VO
: PRINT USING R$(14);EC
:PRINT" "
:GOSUB 4750
:RETURN
5740 '
5750 ' POND SIZE, POND COST SUBROUTINE
5760 '
5770 IFFI$="Y"GOTO5790
5780 PS=8.267E-2*AQ*CF
:PF=13648.0*PS[.583
:RETURN
5790 FQ=0.7*AQ
```

```
:PS=8.267E-2*(AQ+FQ)*CF
:PC=13648.0*PS[.583
:FS=8.267E-2*FQ*CF
5800 FC=13648.0*FS[.583
:PF=PC-FC
:RETURN
:END
:END
5810 '
5820 ' HARD COPY SUBROUTINE
5830  PRINT
:PRINT"PRESS H FOR HARDCOPY OR ANY OTHER KEY TO CONTINUE"
:GOSUB 2340
:IF X$<>"H" THEN RETURN
5840 GOSUB 3130
: IF UN$="E" THEN JS=1
:GOSUB 2000
5850 IF UN$="E" THEN X(22)=(X(22)+40)*(9/5)-40
5860 IF PEEK(14312)<>60 THEN PRINT
: PRINT "      PRESS <ENTER> WHEN THE LINE PRINTER IS READY "
: GOSUB 2340
5870 LPRINT"OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1";
:LPRINT "         PAGE 1 OF 3"
5880 LPRINT" "
5890 LPRINT"PLANT : ";P$
5900 LPRINT"DATE : ";DT$
5910 LPRINT"REMARKS : ";RE$
5920 LPRINT" "
:LPRINT TAB(35) "PLANT DATA"
5930 LPRINT STRING$(80,"=")
5940 FOR J%=1 TO 21
5950 LPRINT TAB(5) USING F$(J%);X(J%);
:LPRINT C$(J%,M)
5960 NEXT J%
5970 LPRINT CHR$(12)
5980 LPRINT"OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1";
:LPRINT "         PAGE 2 OF 3"
5990 LPRINT CHR$(10)"PLANT : ";P$CHR$(10)"DATE : ";DA$
6000 LPRINT CHR$(138)TY$(A);" NAME : ";NM$ CHR$(10) "REMARKS : ";CM$
6010 LPRINT TAB(40-LEN(TY$(A))/2) TY$(A);" DATA" CHR$(10) STRING$(80,"=")
6020 FOR J%=22 TO JF
:LPRINT"     ";
:LPRINT USING  F$(J%);X(J%);
:LPRINTC$(J%,M)
6030 NEXT J%
6040 LPRINT CHR$(12)
6050 LPRINT"OUTPUT FROM PARTICULATE CONTROL COST MODEL VERSION 1.1";
:LPRINT "         PAGE 3 OF 3"
6060 LPRINT CHR$(10)"PLANT : ";P$CHR$(10)"DATE : ";DA$
6070 LPRINT CHR$(138)TY$(A);" NAME : ";NM$ CHR$(10) "REMARKS : ";CM$
6072 LPRINT " "
:LPRINT TAB(37) "RESULTS"
```

```
:LPRINT STRING$(79,"*")
:LPRINT" "
6075 BL$="         "
6080 LPRINT BL$;
:LPRINT USING R$(1);ZC
:LPRINT BL$;
:LPRINT USING R$(2);DC
:LPRINT BL$;
:LPRINT USING R$(3);AC
:LPRINT BL$;
:LPRINT USING R$(4);IC
:LPRINT BL$;
:LPRINT USING R$(5);PC
:LPRINT BL$;
:LPRINT USING R$(6);CB
6090 LPRINT BL$;
:LPRINT USING R$(7);M6
:LPRINT BL$;
:LPRINT USING R$(8);FD
:LPRINT BL$;
:LPRINT USING R$(9);EN
:LPRINT BL$;
:LPRINT USING R$(10);CA
:LPRINT BL$;
:LPRINT USING R$(11);CC
:LPRINT " "
6100 LPRINT BL$;
:LPRINT USING R$(12);FO
:LPRINT BL$;
:LPRINT USING R$(13);VO
:LPRINT BL$;
:LPRINT USING R$(14);EC
:LPRINT BL$;
:LPRINT USING R$(15);A1
:LPRINT BL$;
:LPRINT USING R$(16);LV
6110 LPRINT CHR$(12)
6120 IF UN$="E" THEN GOSUB 2000
6130 IF UN$="E" THEN X(22)=(X(22)+40)*5/9-40
6140 RETURN
6150 ' STORE PLANT DATA
6160 LSET Z$(1)=MKI$(X(1))
: LSET Z$(13)=MKI$(X(13))
6170 FOR I%=2 TO 3
:LSET Z$(I%)=MKI$(X(I%)*10)
:NEXT I%
:LSET Z$(5)=MKI$(X(5))
6180 FOR I%=7 TO 10
:LSET Z$(I%)=MKI$(X(I%)*100)
:NEXT I%
6190 LSET Z$(4)=MKS$(X(4))
:LSET Z$(6)=MKS$(X(6))
```

```
6200 FOR I%=14 TO 21
:LSET Z$(I%)=MKI$(X(I%)*100)
:NEXT I%
6210 LSET FG$=FI$
:LSET RM$=RE$
6220 LSET DT$=DA$
6230 LSET Z$=P$
6240 OPEN"R",1,F$
: PUT 1,PR%
: CLOSE
6250 RETURN
6260 END
6270 IF PR%=1 THEN 6280 ELSE GOSUB 6150
6280 OPEN"R",1,F$
6290 FIELD 1,135 AS DUM$,2 AS N$,8 AS ES$,2 AS Z$(22),2 AS Z$(23),2 AS Z$(24)
6300 FIELD 1,151 AS DUM$,4 AS Z$(25),4 AS Z$(26),2 AS Z$(27),2 AS Z$(28)
6310 FIELD 1,163 AS DUM$,2 AS Z$(29),2 AS Z$(30),2 AS Z$(31),2 AS Z$(32)
6320 FIELD 1,171 AS DUM$,2 AS Z$(33),1 AS ET$,33 AS NULL$,40 AS EM$
6330 LSET N$=MKI$(A)
:LSET Z$(23)=MKI$(X(23))
:LSET Z$(26)=MKS$(X(26))
:LSET Z$(22)=MKI$(X(22))
:X(25)=X(25)/1E8
:LSET Z$(25)=MKS$(X(25))
:LSET Z$(24)=MKI$(X(24)*100)
6340 FOR I%=27 TO 33
:LSET Z$(I%)=MKI$(X(I%)*100)
:NEXT
6350 LSET ES$=NM$
6360 LSET ET$=STR$(ET)
6370 LSET EM$=CM$
: GOSUB 7220
6380  PUT 1,PR%
: CLOSE
6390 PR%=PR%+1
6400 RETURN
6410 IF PR%=1 THEN 6420 ELSE GOSUB 6150
6420 OPEN"R",1,F$
6430 FIELD 1,135 AS DUM$,2 AS N$,8 AS VE$,2 AS Z$(22),2 AS Z$(23),4 AS Z$(24)
6440 FIELD 1,153 AS DUM$,2 AS Z$(25),2 AS Z$(26),2 AS Z$(27),2 AS Z$(28)
6450 FIELD 1,161 AS DUM$,2 AS Z$(29),2 AS Z$(30),2 AS Z$(31),2 AS Z$(32)
6460 FIELD 1,169 AS DUM$,2 AS Z$(33),36 AS NULL$,40 AS VT$
6470 X(24)=X(24)*1000
:X(25)=X(25)*100
6480 FOR I%=27 TO 33
:X(I%)=X(I%)*100
:NEXT
6490 FOR I%=31 TO 33
: X(I%)=X(I%)*10
: NEXT
6500 LSET N$=MKI$(A)
:LSET Z$(22)=MKI$(X(22))
```

```
:LSET Z$(24)=MKS$(X(24))
6510 FOR I%= 25 TO 33
: LSET Z$(I%)=MKI$(X(I%))
:NEXT
6520 LSET Z$(23)=MKI$(X(23))
:LSET VE$=NM$
:LSET VT$=CM$
6530 GOSUB 7220
6540  PUT 1,PR%
: CLOSE
:PR%=PR%+1
:RETURN
6550 IF PR%=1 THEN 6560 ELSE GOSUB 6150
6560 OPEN"R",1,F$
6570 FIELD 1,135 AS DUM$,2 AS N$,8 AS FT$,2 AS Z$(22),2 AS Z$(23),4 AS Z$(24)
6580 FIELD 1,153 AS DUM$,4 AS Z$(25),4 AS Z$(26),2 AS Z$(27),2 AS Z$(28)
6590 FIELD 1,165 AS DUM$,2 AS Z$(29),2 AS Z$(30),2 AS Z$(31),2 AS Z$(32)
6600 FIELD 1,173 AS DUM$,2 AS Z$(33),2 AS Z$(34),2 AS Z$(35),2 AS Z$(36)
6610 FIELD 1,181 AS DUM$,2 AS Z$(37),2 AS Z$(38),2 AS Z$(39),2 AS Z$(40)
6620 FIELD 1,189 AS DUM$,2 AS Z$(41),2 AS Z$(42),14 AS NULL$,40 AS FR$
6630 LSET Z$(22)=MKI$(X(22))
:FOR I%=24 TO 26
:LSET Z$(I%)=MKS$(X(I%))
:NEXT I%
6640 LSET Z$(27)=MKI$(X(27))
:LSET Z$(28)=MKI$(X(28))
:LSET Z$(39)=MKI$(X(39))
:LSET Z$(40)=MKI$(X(40))
:LSET Z$(42)=MKI$(X(42))
:X(41)=X(41)*100
:LSET Z$(41)=MKI$(X(41))
6650 FOR I%=29 TO 38
:X(I%)=X(I%)*100
:LSET Z$(I%)=MKI$(X(I%))
:NEXT I%
6660 LSET Z$(23)=MKI$(X(23))
:LSET N$=MKI$(A)
6670 LSET FT$=NM$
:LSET FR$=CM$
: GOSUB 7220
:  PUT 1,PR%
: CLOSE
:PR%=PR%+1
:RETURN
6680 '
6690 IF PR%=1 THEN RETURN
6700 PRINT "CHECKING FOR EXISTING FILE"
:OPEN"R",1,F$
6710 FIELD 1,135 AS DUM$,2 AS N$,8 AS ES$,2 AS Z$(22),2 AS Z$(23),2 AS Z$(24)
6720 FIELD 1,151 AS DUM$,4 AS Z$(25),4 AS Z$(26),2 AS Z$(27),2 AS Z$(28)
6730 FIELD 1,163 AS DUM$,2 AS Z$(29),2 AS Z$(30),2 AS Z$(31),2 AS Z$(32)
6740 FIELD 1,171 AS DUM$,2 AS Z$(33),1 AS ET$,33 AS NULL$,40 AS EM$
```

```
6750 SR%=PR%-1
6760 FOR I%=1 TO SR%
: GET 1,I%
: A=CVI(N$)
6770 IF ((A=1 OR A=3) AND NM$=ES$) THEN 6790
6780 NEXT I%
: CLOSE
: RETURN
6790 X(24)=CVI(Z$(24))/100.0
: X(26)=CVS(Z$(26))
: X(22)=CVI(Z$(22))
6800 X(23)=CVI(Z$(23))
: X(25)=CVS(Z$(25))*1E8
6810 FOR I%=27 TO 33
: X(I%)=CVI(Z$(I%))/100.0
: NEXT I%
6820 CLOSE
: GOSUB 7190
: GOSUB 4780
: GOSUB 4010
: JF=33
: GOSUB 5820
6830 FL=1
: RETURN
6840 '
6850 IF PR%=1 THEN RETURN
6860 PRINT "CHECKING FOR EXISTING FILE"
:OPEN"R",1,F$
6870 FIELD 1,135 AS DUM$,2 AS N$,8 AS FT$,2 AS Z$(22),2 AS Z$(23),4 AS Z$(24)
6880 FIELD 1,153 AS DUM$,4 AS Z$(25),4 AS Z$(26),2 AS Z$(27),2 AS Z$(28)
6890 FIELD 1,165 AS DUM$,2 AS Z$(29),2 AS Z$(30),2 AS Z$(31),2 AS Z$(32)
6900 FIELD 1,173 AS DUM$,2 AS Z$(33),2 AS Z$(34),2 AS Z$(35),2 AS Z$(36)
6910 FIELD 1,181 AS DUM$,2 AS Z$(37),2 AS Z$(38),2 AS Z$(39),2 AS Z$(40)
6920 FIELD 1,189 AS DUM$,2 AS Z$(41),2 AS Z$(42),14 AS NULL$,40 AS FR$
6930 SR%=PR%-1
6940 FOR I%=1 TO SR%
: GET 1,I%
: A=CVI(N$)
6950 IF A=4 AND FT$=NM$ THEN 6970
6960 NEXT I%
: CLOSE
: RETURN
6970 X(27)=CVI(Z$(27))
:X(28)=CVI(Z$(28))
:X(39)=CVI(Z$(39))
:X(40)=CVI(Z$(40))
:X(42)=CVI(Z$(42))
:X(41)=CVI(Z$(41))/100.0
6980 X(22)=CVI(Z$(22))
: X(23)=CVI(Z$(23))
: FOR I%=24 TO 26
: X(I%)=CVS(Z$(I%))
: NEXT I%
6990 FOR I%=29 TO 38
: X(I%)=CVI(Z$(I%))/100
:NEXT I%
: CLOSE
7000 GOSUB 7190
: GOSUB 4780
: GOSUB 4430
: JF=42
: GOSUB 5820
7010 FL=1
: RETURN
7020 '
7030 IF PR%=1 THEN RETURN
7040 PRINT "CHECKING FOR EXISTING FILE"
:OPEN"R",1,F$
7050 FIELD 1,135 AS DUM$,2 AS N$,8 AS VE$,2 AS Z$(22),2 AS Z$(23),4 AS Z$(24)
7060 FIELD 1,153 AS DUM$,2 AS Z$(25),2 AS Z$(26),2 AS Z$(27),2 AS Z$(28)
7070 FIELD 1,161 AS DUM$,2 AS Z$(29),2 AS Z$(30),2 AS Z$(31),2 AS Z$(32)
7080 FIELD 1,169 AS DUM$,2 AS Z$(33),36 AS NULL$,40 AS VT$
7090 SR%=PR%-1
7100 FOR I%=1 TO SR%
: GET 1,I%
: A=CVI(N$)
7110 IF (A=2 OR A=3) AND VE$=NM$ THEN 7130
7120 NEXT I%
: CLOSE
: RETURN
7130 X(22)=CVI(Z$(22))
:X(23)=CVI(Z$(23))
:X(24)=CVS(Z$(24))/1000
7140 FOR I%=25 TO 33
: X(I%)=CVI(Z$(I%))/100
: NEXT I%
: CLOSE
7150 FOR I%=31 TO 33
: X(I%)=X(I%)/10
: NEXT
7160 X(26)=X(26)*100
7170 GOSUB 7190
: GOSUB 4780
: GOSUB 4210
: JF=33
: GOSUB 5820
7180 FL=1
: RETURN
7190 '
7200 CC=CVI(CC$)*1E4
: FO=CVI(FO$)*1E3
: VO=CVI(VO$)*1E3
: EC=CVI(EC$)*1E3
7210 RETURN
```

```
7220 '
7230 LSET CC$=MKI$(CC/1E4)
:LSET FO$=MKI$(FO/1E3)
:LSET VO$=MKI$(VO/1E3)
:LSET EC$=MKI$(EC/1E3)
: RETURN
7240 '  DIRECTORY LISTING SUBROUTINE
7250 PRINT
: PRINT "     DO YOU WISH TO REVIEW THE EXISTING CASES FOR THIS PLANT ?";
: GOSUB 2140
7260 IF X$="N" THEN RETURN
7270 OPEN"R",1,F$
:GOSUB 2100
: FIELD 1,135 AS DUM$, 2 AS N$,8 AS NM$,62 AS NULL$,40 AS R$
7280 SR%=PR%-1
7290 FOR I%=1 TO SR%
: GET 1,I%
: A=CVI(N$)
7300 PRINT@ 260,"RECORD #
: ";I%
7310 PRINT@ 291,"DATE
: ";DT$
7320 PRINT@ 324,"TYPE
:         "
:PRINT@ 331,TY$(A)
7330 PRINT@ 355,"NAME
: ";NM$
7340 PRINT@ 388,"REMARKS
: ";R$
7350 PRINT
: PRINT "PRESS (ENTER) WHEN READY TO CONTINUE"
: GOSUB 2340
7360 NEXT I%
7370 GOSUB 2100
: PRINT "     FILE LISTING COMPLETE"
7380 PRINT "     DO YOU WANT A HARDCOPY OF THIS DIRECTORY ? ";
: GOSUB 2140
7390 IF X$="N" THEN CLOSE
: RETURN
7400 IF PEEK(14312)()63 THEN PRINT
: PRINT "     PRESS (ENTER) WHEN THE LINE PRINTER IS READY "
: GOSUB 2340
7410 LPRINT " "
: LPRINT "DIRECTORY LISTING FOR FILE ";F$,,"DATE
: ";DA$
7420 LPRINT " "
7430 FOR I%=1 TO SR%
: GET 1,I%
: A=CVI(N$)
7440 LPRINT "RECORD #
: ";I%,,"DATE
: ",DT$
```

```
7450 LPRINT "TYPE
: ";TY$(A),,"NAME
: ";NM$
7460 LPRINT "REMARKS
: ";R$
:LPRINT " "
7470 NEXT I%
7480 LPRINT " FILE LISTING COMPLETE"
: CLOSE
: LPRINT CHR$(12)
: RETURN
```

End of COST program listing

APPENDIX D

PROGRAM CROSS REFERENCE

APPENDIX D

PROGRAM CROSS-REFERENCE

This listing was made with the REF function of the NEWDOS/80$^{=}$ operating system. It will prove to be invaluable to anyone wishing to make extensive revisions to the program. The listing is divided into a number cross-reference and a variable cross-reference. The number cross-reference can be used to locate a line number, a constant, or any occurrence of any integer numbers in the program. The list is of the form:

```
#   ln1(/p1) ln2(/p2) ln3(/p3)  . . .
```

where # is any given number to be found (e.g., 1, 10, 100, 5750, etc...) and ln1 is the line number in the program where that number first appears, ln2 is the line number in the program where the number appears a second time, etc. If a number appears more than once in a given line then the line number will be followed by a /p where p is the number of times that number (#) appears in that line (ln). For example, to find where the number 33 occurs in the program, locate 33 in the left column of the listing (the numbers appear in increasing order). The number 33 appears in line numbers 890, 920, 980,.... Note that 33 appears twice in line number 4360 (i.e., 4360/2).

The variable cross-reference listing is similar to the number listing. It has the same format, yet it is a little more complicated because a variable name that begins with a given letter can be used as a string, a constant, and an array all at once. For example, there are two arrays in the program that have letter names C. One array contains numbers (C), the other array contains strings (C$). Find the listing for the variable C in the variable cross-reference. It looks something like this:

```
C    130( 130($ ...

                    ...4160(3 4170($4 ... etc...
```

This listing means that the number array C appears once in line 130 and three times in line 4160. The string array C$ also appears once in line 130 and 4 times in line 4170. The parenthesis to the right of the line numbers indicates that they are arrays.

This cross reference will not be important until you are interested in making changes in the program and need to locate a variable or number to change it. When you do need to use it, this listing will be easy to follow after a little practice.

```
 0  210 220 290 300/2 310 320 620 660 680 820 850 1050
    1080 1150 1340 1370 1420 1440 1620 1680 1740 1810/2
    2020 2030 2040 2150 2280 2330 2400 2410 2510 3380
    3390/5 4150 4170/2 4180/2 4360 4370/2 4380/2 4670
    4680/4 4690
 1  115 120 230/2 240 250 330 340/2 360 370 390 400 420
    440/2 450/2 470/3 490 520 540 740 780 820 860/2 880/2
    890/2 910 940 960 1000/2 1010/2 1030/3 1050 1150
    1170/2 1200 1230 1250 1290/2 1300/2 1320/3 1340 1440
    1460/2 1480 1510 1530 1570/2 1580/2 1600/3 1620 1750
    1770 1820/2 1830 1850 1870 1880/2 1890 1900 1910
    1920/2 1930 1940/5 1950/2 2010 2020 2030/2 2130 2290
    2300 2310 2320 2400 2410 2460 2510 3160 3370/2 3380/2
    3390/5 3400 3440 4150 4160 4170/2 4180/2 4360/2 4370/2
    4380/2 4390 4400 4670/2 4680/4 4690 4780/3 4870 4900
    4940 5260 5270 5320 5330 5430 5480/3 5490/4 5530/4
    5680 5710 5840 5940 6080 6160/2 6240/2 6270 6280
    6290 6300 6310 6320/2 6330 6380 6390 6410 6420 6430
    6440 6450 6460 6540/2 6550 6560 6570 6580 6590 6600
    6610 6620 6670/2 6690 6700 6710 6720 6730 6740/2
    6750 6760/2 6770 6800 6830 6850 6860 6870 6880 6890
    6900 6910 6920 6930 6940/2 7010 7030 7040 7050 7060
    7070 7080 7090 7100/2 7180 7200/4 7230/4 7270/2 7280
    7290/2 7430/2
 2  120 130 340 360 380 440 450 740 860 890 920 930 1000
    1010 1170 1180 1210 1220 1290 1300 1390 1460 1490
    1500 1570 1580 1770 1880/5 1890/5 1900/4 1910/4 1920
    1930/4 1950/2 3170 3400 3450 4710 4730 4910 4940
    5450 5660 5710 5780 5790/2 6010 6080 6170 6290/4
    6300/2 6310/4 6320 6430/3 6440/4 6450/4 6460 6570/3
    6580/2 6590/4 6600/4 6610/4 6620/2 6710/4 6720/2
    6730/4 6740 6870/3 6880/2 6890/4 6900/4 6910/4 6920/2
    7050/3 7060/4 7070/4 7080 7110 7270
 3  120 880 1130 1180 1770 1840 1880 1950/2 3180 3370/2
    3400 3460 4390 4400 4940 5190 5510 5520 5710 6080
    6170 6770 7110
 4  120 260/2 1460 1760 1770 1830 1880/3 1890 1950/2
    3190 3370 3390/2 3400 3470 4940 5710 6080 6190/2
    6300/2 6430 6570 6580/2 6720/2 6870 6880/2 6950 7050
 5  890 1050 1170 1340 1460 1620 1770 1830 1880 1950/2
    3200 3370 3390/2 3400 3480 4940 5290 5710 5850 5950
    6080 6130 6170/2
 6  780 910 920 1030 1200 1210 1320 1770 1880 1950/2
    2130 3210 3410 3490 4940 5060/2 5180 5490/4 5530/4
    5580 5680 5710 6080 6190/2
 7  1770 1890 1960 2390 3220 3410 3495 4710 4730 4940
    5710 6090 6180
 8  150 260 810/2 1150 1440 1770 1890 1920/2 2130 2510
    3230 3410 3500 4950 5440 5720 6090 6290 6430 6570
    6710 6870 7050 7270
 9  890 1050 1170 1340 1460 1620 1790 1890 3240 3410
    3510 4890 4950 5720 5850 6090 6130
10  360 370 470 570 580 1090 1380 1480 1600 1690 1790
    1820 1850 1890 1960 2300 3250 3420 3520 4190 4950
    5720 5990/2 6000 6010 6060/2 6070 6090 6170 6180
    6490 7150
11  360 370 1490 1810/2 1890 1980/2 3260 3370 3390/2
    3530 4950 4962 5720 5726 6090
12  1740/2 1830 1890 1980/2 3270 3370 3390/2 3540 4400
    4962 5726 5970 6040 6100 6110 7480
13  1750 1790 1820 1900 1970/2 2300 2500 3280 3370 3390/2
    3420 3550 4962 5726 6100 6160/2
14  1800 1830 1900 1970 3290 3430 3560 4720 4962 5726
    6100 6200 6620 6920
15  1790 1830 1900 3300 3410 3430 3570 4780 4930 5670
```

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```
     6100
16   1790 1830 1890 1900 3310 3430 3580 4700 4790 6100
17   1790 1830 1910 3320 3430
18   1800 1830 1910 3330 3430 5700
19   1800 1910 3340 3430 4960 5700 5724/2
20   130 1750 1800 1910 3350 3410/2 3420 4190 4200 4700
     5480
21   330 370 420 1030 1320 1600 1800 1920 1970 3360 3370
     3380 3420 5940 6200
22   860/2 890/3 910 980 1050/2 1060 1170/3 1200 1270
     1340/2 1350 1460/3 1480 1550 1620/2 1630 4030 4150
     4160 4180/2 4240 4360/2 4380/2 4400 4460 4670/2 4680/2
     4700 5850/2 6020 6130/2 6290 6330/2 6430 6500/2 6570
     6630/2 6710 6790/2 6870 6980/2 7050 7130/2
23   720 1060 1350 1630 2130 4040 4190 4250 4400 4470
     4700 4780 6290 6330/2 6430 6520/2 6570 6660/2 6710
     6800/2 6870 6980/2 7050 7130/2
24   1060 1350 1630 2520 4050 4200 4260 4400 4480 4680/2
     4690 4700 4920 4960 6290 6330/2 6430 6470/2 6500/2
     6570 6630 6710 6790/2 6270 6980 7050 7130/2
25   1060 1350 1630 4060 4180/2 4190 4270 4370/2 4390
     4400 4490 4680/2 4690 4700 6300 6330/4 6440 6470/2
     6510 6580 6720 6800/2 6880 7060 7140
26   1060 1350 1630 2300 4070 4160 4170/2 4200 4280 4400
     4500 4680/2 4690 4700 6300 6330/2 6440 6580 6630
     6720 6790/2 6880 6980 7060 7160/2
27   910 1060 1200 1350 1630 2290 4080 4160 4170/2 4200
     4290 4400 4510 4700 6300 6340 6440 6480 6580 6640/2
     6720 6810 6880 6970/2 7060
28   570 580/2 920 1060 1210 1350 1630 4090 4190 4300
     4400 4520 4710 6300 6440 6580 6640/2 6720 6880 6970/2
     7060
29   1060 1360 1640 4100 4190 4310 4370/2 4390 4400 4530
     4710 6310 6450 6590 6650 6730 6890 6990 7070
30   720 740 780 1060 1360 1640 1900 2210 2220 3410 4110
     4190 4320 4380/2 4390 4400 4540 4700 4710 6310 6450
     6590 6730 6890 7070
31   1060 1350 1480 1650 2530 4120 4190 4330 4410 4550
     4690/3 4710 6310 6450 6490 6590 6730 6890 7070 7150
32   410 970 1070 1260 1350 1490 1540 1650 1830/2 2360
     4130 4190 4340 4410 4560 4720 6310 6450 6590 6730
     6890 7070
33   890 920 980 1070 1170 1210 1270 1350 1660 4140 4150
     4160 4190 4350 4360/2 4410 4570 4720 6320/2 6340
     6460 6480 6490 6510 6600 6740/2 6810 6820 6900 7080
     7140 7150 7170
34   1640 4580 4720 6600 6900
35   1660 4590 4720 5920 6600 6900
36   1670 4600 4730 6460 6600 6900 7080
37   1670 4610 4730 6072 6610 6910
38   1670 1910 3420 4400 4620 4730 6610 6650 6910 6990
39   1670 4630 4730 6610 6640/2 6910 6970/2
40   830 890/2 1050/2 1160 1170/2 1340/2 1450 1460/2 1620/2
     1670 4640 4700 4730 5850/2 6010 6130/2 6320 6460
     6610 6620 6640/2 6740 6910 6920 6970/2 7080 7270
41   1640 4650 4710 6620 6640/4 6920 6970/2
42   130/5 1460 1490 1550 1640 4660 4670/2 4710 6620 6640/2
     6920 6970/2 7000
43   3400
44   400 960 1250
45   2250/2
46   1530 1920
55   4200
60   3430 5860
62   2250 7270
63   350/2 900/2 1190/2 1470/2 2060 2090 2110/2 2570 2590
```

```
        3100 4930 4960 5700 5724 7400
   64   2250 2270 2390 2480 2720 3020
   70   1920 3400
   79   6072
   80   4190 5340 5930 6010
   91   2290 2800
   92   2790
   93   2210
   95   2360 2480
  100   1060 1350/2 1660 1770/2 1780 1790 1800 4960 5724
        6180 6200 6330 6340 6470 6480 6640 6650 6990 7140
        7160
  126   2250 2270
  128   2390 2480
  135   6290 6430 6570 6710 6870 7050 7270
  138   6000 6070
  150   860 4400 4700 5160
  151   6300 6720
  153   6440 6580 6880 7060
  161   6450 7070
  163   6310 6730
  165   6590 6890
  169   6460 7080
  171   6320 6740
  173   6600 6900
  181   6610 6910
  189   6620 6920
  190   700
  210   210
  215   1360/2 1650/2 1780 5070/2 5200/2
  220   230 240 250
  240   4710
  247   1930
  260   220 7300
  270   3400
  273   1090/2 1380/2 1690/2 5340/2
  291   7310
  300   310 3400
  324   7320
  325   860
  331   7320
  350   430 440 450 480
  355   7330
  388   7340
  400   410 5450
  472   5130
  490   420
  500   3400
  550   320 690
  560   4710
  600   600 620
  660   660/2
  680   680
  710   670
  760   1770 1830/2
  800   630
  810   810
  840   850
  896   390/2 940/2 1230/2 1510/2 2210
  900   1000 1010 1040
  960   970
 1000   1770 5090 5220 6470 7130
 1040   990
 1050   980
 1100   1080
 1150   630 1130
```

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```
1190  1280 1290 1300 1330
1250  1260
1335  5050
1340  1270
1390  1370
1440  630
1470  1560 1570 1580 1610
1530  1540
1620  1550
1700  1680
1730  290 500
1760  1740
1850  1810
1860  290
2000  100 330 490 890 1050 1170 1340 1460 1620 5840 6120
2060  140 190
2100  490 550 640 800 1150 1440 7270 7370
2120  1100 1400 1700
2140  170 510 870 7250 7380
2150  2150
2160  390/2 950 1240 1520
2210  460 1020 1310 1590
2240  400 960 1250 1530 2330
2340  300 680 840 2150 2260 2490 4955 5500 5722 5830 5860
      7350 7400
2350  2350
2380  460 1020 1310 1590
2410  2400 2420
2430  2400 2410
2450  2400
2480  2540
2550  180 430 990 1280 1560
2710  2710
2860  2860
3010  3010
3120  3120
3130  330 5840
3229  5060 5180
3400  330
3440  140
3600  5440
4010  890 6820
4190  890
4210  1170 7170
4400  1170
4430  1460 7000
4700  1460
4750  4962 5540 5726
4780  6820 7000 7170
4800  1110 1390
4840  1110
4890  4870
4970  4900
5020  5000
5050  5010
5100  4910
5150  5130
5180  5140
5230  1400
5380  5340
5420  5370
5540  5520
5550  1700
5770  1850
5790  5770
5820  1120 1410 1710 6820 7000 7170
```

```
 6150  540 6270 6410 6550
 6270  1120
 6280  6270
 6410  1410
 6420  6410
 6550  1710
 6560  6550
 6680  820
 6790  6770
 6840  1440
 6970  6950
 7020  1150
 7130  7110
 7190  6820 7000 7170
 7220  6370 6530 6670
 7240  290
 7788  5060
 8760  5050 5060/2 5070 5090 5180 5190 5200 5220 5440 5450
14312  5860 7400
16922  150
16923  150
16924  150
23240  3420
    A  110/$ 660/$ 680/$ 880/2 1130 1180/2 1390 1420 1460
       2150/$ 4870 5510 5520 6000 6010/2 6070 6330 6500
       6660 6760 6770/2 6940 6950 7100 7110/2 7290 7320
       7430 7450
   A1  4780/3 6100
   A8  5580/2 5600/2
   AC  4940 5020 5040 5150 5170 5590 5620 5710 6080
   AD  1070 1670 5060 5180 5680
   AE  4890/2 4930 5050/3 5060/2 5180/3 5190
   AF  1630 5680
   AK  5060 5070 5180 5200 5680 5690
   AM  5050 5070 5180 5200 5660 5690
   AO  4870 5070 5200 5580 5690
   AQ  1850 5350/2 5360/2 5380/2 5390/3 5400/3 5410/2 5450
       5780 5790/2
   AR  1070 1670 5060 5190 5680
   AV  1060 4890 5000 5130
   BA  5640 5650/3 5660 5680/2
   BC  1650 5650/2
   BE  1640 5640
   BL  1640 5640 6075/$ 6080/$6 6090/$5 6100/$5
   BM  5660 5690
   BS  1670 5650
   C   130( 130($ 380($ 930($ 1220($ 1500($ 2010(3 3370(6
       3380($ 3390($10 4150($ 4160(3 4170($4 4180($4 4360(
       4360($ 4370($4 4380($4 4390(3 4670( 4670($ 4680($8
       4690(4 4690($2 5950($ 6020($
   C1  1790
   C3  5440/2
   C5  5280/2
   C6  4780/2
   C8  5280/2
   C9  5280 5420
   CA  4950 5050 5080 5180 5210 5430 5440 5630 5640 5720
       6090
   CB  4940 5030 5040 5160 5170 5610 5620 5710 6080
   CC  1930/$ 4780 4830 4950 4962 5080 5210 5490/2 5530
       5640 5720 5726 6090 7200 7200/$ 7230 7230/$
   CD  1060 4890
   CE  1360/2 1650/2 1770 1780 4880 5030 5070/2 5160 5200/2
       5440 5460/4 5610/2 5690/2
   CF  1770 5070 5080 5200 5210 5460 5470 5690/2 5780 5790/2
   CG  5260/2 5270 5280 5290/2 5300 5440 5450/2
```

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```
CH   5450 5460
CI   1780 5010 5020/4 5040 5140 5150/3 5170/2 5580 5590/2
     5600/2
CK   1770 5080 5210 5460 5690
CM   830/$3 1160/$3 1450/$3 6000/$ 6070/$ 6370/$ 6520/$
     6670/$
CN   300 2020 2030/2 2040
CO   400 960 1250 1530 2250 2270 2390 2460/2 2480
CP   4830 4960 5090 5220 5480/2 5530 5690 5724
CQ   5440/2 5480 5490
CR   5350 5360 5380 5390 5400 5410 5420
CS   5160/2
DA   150/$3 5990/$ 6060/$ 6220/$ 7410/$
DC   4940 5020 5040 5150 5170 5280 5290 5300 5310/2 5420
     5590 5620 5710 6080
DD   2280 2290 2300 2310 2330
DP   1060 1090 1630 1690 5030 5160 5670
DR   5430/4 5440
DT   1920/$ 5900/$ 6220/$ 7310/$ 7440/$
DU   1890/$ 1900/$ 1910/$ 1920/$ 1930/$ 6290/$ 6300/$
     6310/$ 6320/$ 6430/$ 6440/$ 6450/$ 6460/$ 6570/$
     6580/$ 6590/$ 6600/$ 6610/$ 6620/$ 6710/$ 6720/$
     6730/$ 6740/$ 6870/$ 6880/$ 6890/$ 6900/$ 6910/$
     6920/$ 7050/$ 7060/$ 7070/$ 7080/$ 7270/$
E    3370/2 4400 4890 5060/2 5180 5190 5280 5450 5490/4
     5530/4 5680 5780 5790/2
E1   4190
E3   5480/2 7200/3 7230/3
E4   4870/2 4890 5440 5580/2 7200 7230
E5   1820 1850 5020/2 5150  5590/2 5680
E6   1850 5020/2 5040 5140  5150/2 5170/2 5580 5600/2
E7   1750
E8   6330 6800
E9   5480
EA   1800
EC   1930/$ 4780 4830 4962  5080 5210 5480/2 5530 5690
     5726 6100 7200 7200/$  7230 7230/$
ED   4940 5020 5040/2 5050  5150 5170 5180
EF   1790 5050 5180 5620
EJ   5460/2 5470
EK   5070 5080 5090 5200 5210 5220
EM   5050 5070 5180 5200 6320/$ 6370/$ 6740/$
EN   4950 5050 5080 5180 5210 5620 5640 5720 6090
EO   4870 5070 5200
EP   1760 1850
EQ   5420/3 5430
ER   5480 5490 5530
ES   6290/$ 6350/$ 6710/$ 6770/$
ET   860/2 4900 4910 6320/$ 6360 6360/$ 6740/$
F    130($ 210/$ 220/$2 230/$2 240/$2 250/$3 260/$4 280/$2
     380($ 930($ 1220($ 1500($ 1870/$ 3160($ 3170($ 3180($
     3190($ 3200($ 3210($ 3220($ 3230($ 3240($ 3250($
     3260($ 3270($ 3280($ 3290($ 3300($ 3310($ 3320($
     3330($ 3340($ 3350($ 3360($ 4030($ 4040($ 4050($
     4060($ 4070($ 4080($ 4090($ 4100($ 4110($ 4120($
     4130($ 4140($ 4240($ 4250($ 4260($ 4270($ 4280($
     4290($ 4300($ 4310($ 4320($ 4330($ 4340($ 4350($
     4460($ 4470($ 4480($ 4490($ 4500($ 4510($ 4520($
     4530($ 4540($ 4550($ 4560($ 4570($ 4580($ 4590($
     4600($ 4610($ 4620($ 4630($ 4640($ 4650($ 4660($
     5950($ 6020($ 6240/$ 6280/$ 6420/$ 6560/$ 6700/$
     6860/$ 7040/$ 7270/$ 7410/$
FA   1800
FC   5800/2
FD   4950 5010 5040 5050/2 5080 5140 5170 5180/2 5210
     5620/2 5630 5640 5720 6090
```

```
FE  5340 5420
FF  5580 5620/2 5710
FG  1920/$ 6210/$
FH  5340/2 5460/3
FI  520/$ 5270/$ 5340/$ 5420/$ 5460/$ 5470/$ 5770/$ 6210/$
FJ  5690/3
FK  5070/2 5200/2 5670 5690
FL  820/2 1150/2 1440/2 6830 7010 7180
FO  1930/$ 4780 4830 4962 5070 5200 5480/2 5530 5690
    5726 6100 7200 7200/$ 7230 7230/$
FQ  5790/3
FR  1820 1840 6620/$ 6670/$ 6920/$
FS  5790 5800
FT  6570/$ 6670/$ 6870/$ 6950/$
GB  1080 1090 1370 1380 1680 1690 1810 1830 1840/2
GC  1090 1380 1690 1810 4890 5000/2 5030 5130/2 5160
    5260 5580 5610 5640 5660/2 5670 5680
GD  5310 5420
GF  5000 5010 5020/4 5040 5130 5140 5150/3 5170/2 5580/2
    5590/2 5600/2
GT  1060 1090 1350 1380 1630 1690 5160
H1  1790
HF  1060 1670 5050 5670
HK  1060 5050
HO  5320/2 5330
HP  5030/2 5070 5160/2 5200 5610/2 5670/2
HR  1850/2 5480
HT  5450/2 5470 5480
HV  1790
HX  5330 5420
I   220/%2 230/% 240/% 250/%2 630/2 740/2 780/2 1960/%4
    1970/%4 2130 2400/%3 2410/%4 3370/3 3380/3 4150/3
    4160/%3 4360/6 4670/6 6170/%4 6180/%4 6200/%4 6340/%3
    6480/%3 6490/%3 6510/%3 6630/%4 6650/%6 6760/%2 6780/%
    6810/%4 6940/%2 6960/% 6980/%4 6990/%4 7100/%2 7120/%
    7140/%4 7150/%3 7290/%2 7300/% 7360/% 7430/%2 7440/%
    7470/%
IC  4940 5020 5040 5170/2 5600 5620 5710 6080
IN  5430/2 5440
IR  1770 1780
J   220/% 230/% 240/%2 250/% 380/%5 930/%5 1220/%5 1500/%5
    2010/%7 3380/3 4150/3 4360/3 4670/3 5940/% 5950/%3
    5960/% 6020/%4 6030/%
JF  330 370/2 380 420 890 910 920 930 980 1170 1200 1210
    1220 1270 1460 1480 1490 1500 1550 2010 6020 6820
    7000 7170
JS  330 360/2 380 420 890 910 920 930 980 1170 1200 1210
    1220 1270 1460 1480 1490 1500 1550 2010 5840
KA  5060 5070 5190 5200 5680 5690
KH  5050 5070 5670 5690
LB  5640 5650/2
LF  1060 1640 5070 5200 5670
LG  1350 5310 5320 5440 5450
LP  1060 1350 1630 4780/3
LR  1650 5650 5660/2
LS  5440 5460
LV  4780 4790 6100
M   300 380 490 930 1050 1220 1340 1500 1620 2020 2030
    5950 6020
MS  5270 5280/4 5290 5300 5310/2 5320 5330/2 5340
M6  4940 5040/2 5170/2 5600 5620 5710 6090
MC  1770 5050 5180 5430 5630
MD  1630 5260/5 5270/4 5280 5310/4 5330/3 5340 5580 5670
MF  5580/2 5590 5600/2 5660
MH  5340/2
ML  5660/2
```

```
MO  1660 5650/2
MT  5440 5460/2
MX  360 370 470 910 920 1030 1200 1210 1320 1480 1490
    1600 2310 2320
N   6290/$ 6330/$ 6430/$ 6500/$ 6570/$ 6660/$ 6710/$
    6760/$ 6870/$ 6940/$ 7050/$ 7100/$ 7270/$ 7290/$
    7430/$
N2  1800
NB  1640 5660
NF  1060 1660 5070 5200 5670
NH  5050/2
NM  800/$ 810/$5 1150/$5 1440/$5 6000/$ 6070/$ 6350/$
    6520/$ 6670/$ 6770/$ 6950/$ 7110/$ 7270/$ 7330/$
    7450/$
NP  340 350 890 900 1170 1190 1460 1470 5320/5 5330/4
NS  400 960 1050 1250 1340 1530 1620
NU  6320/$ 6460/$ 6620/$ 6740/$ 6920/$ 7080/$ 7270/$
O2  1790
OC  5580 5690
OM  5660 5690
P   210/$3 290/$ 320/$ 340 350/$ 440 450 470/5 890 1000
    1010 1030/5 1170 1290 1300 1320/5 1460 1570 1580
    1600/5 2110/$ 2250 2270 2310/4 2320/2 2390 2480 5890/$
    5990/$ 6060/$ 6230/$
PA  1090/2 1380/2 1690/2 1770
PB  1740 1750 1760 1850
PC  4870 4880 4940 5010 5040 5050 5170 5180 5430/2 5440
    5610 5620 5670 5710 5790 5800 6080
PD  5330 5420
PF  4880 5610 5780 5800
PG  5330/2
PH  5450 5460
PL  1770
PM  5050 5070 5180 5200 5670 5690
PN  340 350 360 370 390 440/2 450/2 470 890 900 910 920
    940 1000/2 1010/2 1030 1170 1190 1200 1210 1230 1290/2
    1300/2 1320 1460 1470 1480 1490 1510 1570/2 1580/2
    1600
PR  540/% 1940/% 6240/% 6270/% 6380/% 6390/%2 6410/%
    6540/%3 6550/% 6670/%3 6690/% 6750/% 6850/% 6930/%
    7030/% 7090/% 7280/%
PS  5780/2 5790/2
QE  1350 5270
QF  1350 5430
QL  1350 5430
QM  1350 5440
R   130($ 3440($ 3450($ 3460($ 3470($ 3480($ 3490($ 3495($
    3500($ 3510($ 3520($ 3530($ 3540($ 3550($ 3560($
    3570($ 3580($ 4780($ 4790($ 4940($7 4950($4 4962($4
    5710($7 5720($4 5726($4 6080($6 6090($5 6120($5 7270/$
    7340/$ 7460/$
RE  270/$ 5910/$ 6210/$
RH  5680 5690
RI  5450 5460
RK  5680/2
RM  1920/$ 6210/$
RO  1060
RS  1360 5450
RW  1360 5440
RX  5440 5460/2
S2  1800
SB  5330 5420
SF  5000 5010 5020/3 5040 5130 5140 5150/2 5170/2
SR  6750/% 6760/% 6930/% 6940/% 7090/% 7100/% 7280/%
    7290/% 7430/%
SZ  1770 1850 5090 5220 5470 5480 5690
```

```
TA  4890/2
TC  5310 5420
TE  1790
TH  5460/2
TK  4890/2
TS  5310/3
TW  4890 5070 5200
TY  120($4 6000($ 6010($2 6070($ 7320($ 7450($
UB  1670 5660
UF  1640 5650 5660
UN  300/$ 310/$ 330/$ 890/$ 1170/$ 1460/$ 5840/$ 5850/$
    6120/$ 6130/$
V   1630 5580 5640/2 5700
VC  5310 5420
VE  5460 5480 5490 6430/$ 6520/$ 7050/$ 7110/$
VF  5460 5480 5490
VO  1930/$ 4780 4830 4962 5070 5200 5480/2 5530 5690
    5726 6100 7200 7200/$ 7230 7230/$
VP  5470 5480/2 5490
VT  6460/$ 6520/$ 7080/$
VV  5460/2 5470/2 5480 5490
W   115/$3 115($ 150($3 1800
X   130( 150/$2 180/$ 300/$2 380( 410 420/$ 430/$ 440/$
    450/$ 470( 520/$ 660/$ 680/$2 690/$ 840/$ 850/$ 860/$
    860(2 880/$3 890(2 930( 970 980/$ 990/$ 1000/$ 1010/$
    1030( 1050(2 1060(10 1070(2 1170(2 1220( 1260 1270/$
    1280/$ 1290/$ 1300/$ 1320( 1340(2 1350(10 1360(2
    1460(2 1500( 1540 1550/$ 1560/$ 1570/$ 1580/$ 1600(
    1620(2 1630(7 1640(5 1650(2 1660(2 1670(5 1740(2
    1750(2 1760( 1770(8 1790(6 1800(5 1810(2 1820(3 1830(6
    1850( 1950(6 1960( 1970(2 1980(2 2010(2 2150/$2 2290/2
    2300/3 2350 2350/$3 2360/4 2360/$ 2470/$ 2500 2510
    2520 2530 2530/$ 3400(5 3410(4 3420(4 3430(6 4190(8
    4200(3 4400(9 4410(3 4700(6 4710(6 4720(4 4730(5
    4780( 5830/$ 5850(2 5950( 6020( 6130(2 6160(2 6170(2
    6180( 6190(2 6200( 6330(7 6340( 6470(4 6480(2 6490(2
    6500(2 6510( 6520( 6630(2 6640(8 6650(3 6660( 6790(3
    6800(2 6810( 6970(6 6980(3 6990( 7130(3 7140( 7150(2
    7160(2 7260/$ 7390/$
X4  5650 5660
X5  5650 5660
X7  5650 5660
X8  5660/2
XE  1350 5460
XH  1350 5450
XP  1350 1380 1630 5280 5340 5480 5610
XR  1780 4780/3
Y   150/$2 470 600/$2 610/$ 620/$ 630/$ 660/$4 670/$
    700/$ 1030 1320 1600 2400/$3 2410/$5 2430 2430/$
    2470/$ 2480/$ 2510/$4 2520/$ 2530/$2 2710/$2 2860/$2
    3010/$2 3120/$2
Z   130($ 150/$2 290/$ 320/$ 1880($6 1890($6 1900($4
    1910($4 1920/$ 1920($ 1950($6 1960($ 1970($2 1980($2
    6160($2 6170($2 6180($ 6190($2 6200($ 6230/$ 6290($3
    6300($4 6310($4 6320($ 6330($5 6340($ 6430($3 6440($4
    6450($4 6460($ 6500($2 6510($ 6520($ 6570($3 6580($4
    6590($4 6600($4 6610($4 6620($2 6630($2 6640($6 6650($
    6660($ 6710($3 6720($4 6730($4 6740($ 6790($3 6800($2
    6810($ 6870($3 6880($4 6890($4 6900($4 6910($4 6920($2
    6970($6 6980($3 6990($ 7050($3 7060($4 7070($4 7080($
    7130($3 7140($
ZC  5040 5050 5180 5620 6080
```

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APPENDIX E

DATA INPUT WORKSHEETS

PLANT INPUT WORKSHEET

Plant: ______________________________
Date: ____________
Remarks: ____
____

PLANT DATA

Boiler size	________	MW net			
Capacity factor	________	%			
Chemical Engineering Plant Cost Index	________				
Emission limit	________	ng/J	or	________	lb/MBtu
Plant altitude	________	m	or	________	ft
Interest rate	________	%/yr			
Cost of electricity	________	mil/kWh			
Contingency as percent of field cost	________	%			
Engineering as percent of field cost	________	%			
Steam cycle efficiency	________	%			
Coal heating value	________	kJ/kg	or	________	Btu/lb
Fraction excess air	________	%			
Percent carbon in coal	________	%			
Percent hydrogen in coal	________	%			
Percent oxygen in coal	________	%			
Percent sulfur in coal	________	%			
Percent nitrogen in coal	________	%			
Percent ash in coal	________	%			
Percent water in coal	________	%			

ESP INPUT WORKSHEET

Plant: ______________________________

Date: ____________

ESP Name: _________________________

Remarks: ____

____

ESP DATA

Gas temperature	______	°C	or	______	°F
Expected ESP life	______	yr			
Current density	______	nA/cm^2			
Fly ash resistivity	______	ohm cm			
Specific collection area	______	$m^2/m^3/s$	or	______	ft^2/kacfm
ESP pressure drop	______	cm H_2O	or	______	inches H_2O
Fan load factor (0 < > 1)	______				
Fan efficiency	______	%			
Hopper heater power	______	kW/hopper			
Hopper heater duty factor (0 < > 1)	______				
Accessories duty factor (0 < > 1)	______				
Ash removal system duty factor (0 < > 1)	______				

BAGHOUSE INPUT WORKSHEET

Plant: ______________________________

Date: ____________

Baghouse Name: _________________________

Remarks: ____

____

BAGHOUSE DATA

Gas temperature	______ °C	or	______ °F
Expected baghouse life	______ yr		
Air-to-cloth ratio	______ m/min	or	______ ft/min
Maximum pressure drop	______ cm H_2O	or	______ inches H_2O
Average pressure drop	______ cm H_2O	or	______ inches H_2O
Number of modules	______		
Reverse air fan size (kW/10^5 m^2 bag area)	______		
Bag life	______ yr		
Bag life exponent	______		
Bag replacement cost	$ ______ /m^2	or	$ ______ /ft^2
Labor rate	$ ______ /h		
Material overhead fraction	______		
Fan load factor	______		
Fan efficiency	______ %		
Hopper heater duty factor	______		
Accessories duty factor	______		
Ash removal system duty factor	______		
Scheduled bag replacement time	______ min/m^2		
Unscheduled bag replacement time	______ min/m^2		
Fraction of unscheduled bag replacements	______		
Nonbag maintenance time (h/yr/1000 cms)	______		

SCRUBBER INPUT WORKSHEET

Plant: ______________________________
Date: ____________

Scrubber Name: _________________________
Remarks: ____
____

SCRUBBER DATA

Gas temperature ________ °C or ________ °F
Expected scrubber life ________ yr
L/G ________
Pressure drop ________ cm H_2O or ________ inches H_2O
Number of spare modules ________
Fan efficiency ________ %
Holding tank pump efficiency ________ %
Water cost $ ________ /m^3 or $ ________ /ft^3
Steam cost $ ________ /GJ or $ ________ /MBtu
Equipment cost fraction ________
Labor cost fraction ________
Maintenance cost fraction ________